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Final Report

REAL TIME OPTICAL ALIGNMENT AND DIAGNOSTIC SYSTEM (ROADS)

Prepared for
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

Contract.No. NAS9-11385

EOS Report 4065-Final 17 November 1972

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SECTION 1

PREFACE

This final report is submitted in compliance with the requirements of NASA Manned Spacecraft Center Contract NAS9-11385. This report covers the period of effort starting 13 April 1971.

This report describes requirements and constraints, optical analysis, system design, and system usage for a Real-Time Optical Alignment and Diagnostic System (ROADS) for use at NASA/Manned Spacecraft Center, Houston, Texas.

Supporting information covering ROADS flow charts, CRT output examples, and the outline of typical ROADS usage operation sequence for ROADS data collection are contained in Appendices to this report.

The complete ROADS software consists of this document, the ROADS Scanner Design Package, the ROADS Installation Checkout and Test Procedures, and the ROADS Alignment Guide.

SECTION 2

SCOPE OF ROADS

The ultimate and most frequent usage of ROADS will be the alignment of subassemblies (collector and collimator) prior to their installation in a chamber. The system as designed has inherent associated capabilities well applied to acceptance testing of the No. 4 mirror, prediction of in-chamber performance, generation of a catalog of test results and other data, providing data for the plotting of iso-intensity lines, and others as discussed in this document. The ROADS system will collect, process, display, analyze, and retain data as required for components, partial subassemblies, complete subassemblies, complete modules, and multimodular arrays.

SECTION 3

REQUIREMENTS AND CONSTRAINTS

3.1 GOALS AND OBJECTIVES

The ROADS design is configured to enable the operator to achieve optimum uniformity attributable to alignment as well as significantly reducing the current manhours required for subassembly alignment.

3.2 MEASURE OF PERFORMANCE

The measure of system performance will be the improvement in uniformity to the limit that can be attributed to alignment. At present, the uniformity attainable is restricted by alignment techniques. The feedback of adjustment errors using the present techniques is extremely difficult to determine. ROADS will give real time feedback at the subassembly level which in itself should improve the intensity uniformity.

3.3 IMPACT ON CURRENT SYSTEM

The most significant impact on the present system will be the reduction in time. Operators of the present system should have little difficulty operating ROADS once they become familiar with it. Familiarity can be achieved by reading the Detail Design and this document, as well as by personal instruction.

SECTION 4

ROADS OPTICAL ANALYSIS

4.1 ENERGY DESCRIPTION

ENERGY is a computer program written specifically for the design and analysis of solar simulator optical systems. A detailed description of ENERGY can be found in Appendix A of EOS Proposal No. 1501 of 10 July 1970. ENERGY is the basis for the mathematical model of subassemblies and subassemblies and modules.

4.2 ANALYSIS

4.2.1 OPTICAL ALIGNMENT ERROR SENSITIVITY

Tables 4-1 and 4-2 show the limit or range of movement for each of the components in both the RCA and the EOS systems. These ranges have been divided into increments according to their sensitivity as defined by ENERGY, thereby establishing the correction that can be achieved with a specific amount of movement or the number of incremental moves. This information will be included in the Alignment Guide.

4.2.2 NOMINAL INTENSITY SURFACES

The ultimate output for a complete module is an intensity of one solar constant at all points on the test plane. The nominal for the complete module is said to be absolute. Because of the nonuniformity of the output of the collector subassembly, specifically high in the center and low at the edge, the collimator subassembly output has to

TABLE 4-1

COLLIMATOR SUBASSEMBLY

RCA SYSTEM

Component	Movement* Axial (z)	Radial (x, y)	Tilt
Field Lens (No. 2 Lens)	No	No	No
No. 3 Mirror	Yes (± 1/4")	Yes (± 1/8")	Yes (± 1/16")
No. 4 Mirror	Yes (± 1/4")	Yes	Yes (± 1/8")
No. 3 Lens	Yes (± 1/4")	Yes (± 1/16")	Yes (± 1/16")
No. 4 Lens	Yes (± 1/4")	Yes (± 1/16")	Yes (± 1/16")

EOS SYSTEM

Component	Axial (z)	Radial (x, y)	Tilt
Field Lens (No. 2 Lens)	No	No	No
No. 3 Mirror	Yes (± 1/4")	Yes	Yes (± 1/8")
No. 4 Mirror	Yes (± 1/4")	No	Yes (± 1/8")
No. 3 Lens, No. 4 Lens	Yes (± 1/8")	Yes (± 1/8")	Yes (± 1/8")

*All movement dimensions are approximate

TABLE 4-2

COLLECTOR SUBASSEMBLY

RCA SYSTEM

Component	Movement* Axial (z)	Radial (x, y)	Tilt
No. 1 Mirror	Yes (± 1/4")	Yes (± 1/32")	Yes (± 1/8")
No. 2 Mirror	Yes (± 1/4")	Yes (± 1/32")	Yes (± 1/8")
No. 1 Lens	Yes (± 1/8")	Yes (± 1/32")	Yes (± 1/16")
Vane Assembly	No	Yes (± 1/16")	No
EOS SYSTEM			
No. 1 Mirror	Yes (± 1/4")	Yes (± 1/32")	Yes (± 1/8")
No. 2 Mirror	Yes (± 1/4")	Yes (± 1/32")	Yes (± 1/8")
No. 1 Lens	Yes (± 1/8")	Yes (± 1/32")	Yes (± 1/16")
Vane Assembly	No	Yes (± 1/16")	No

*All movement dimensions approximate

compensate for it if a uniform test plane is to be the result. Therefore, the desirable output for the collimator is something other than flat (or absolute) and a specific nominal intensity surface must be established. Figures 4-1, 4-2, and 4-3 (see figures 6-2, 6-3, and 6-4) are typical nominal intensity curves. This nominal intensity curve then becomes the goal of alignment of full subsystem collimator subassemblies. The magnitude of deviation is a measure of the quality of the performance of that subassembly. To establish the initial nominal intensity curves, ENERGY has been used, and a collimator subassembly has been set up as close to design position as possible, and measured. Both methods were used and the results of both methods are shown in figure 4-4.

4.2.3 FIGURE OF MERIT

One of the many calculations performed during the alignment procedure is the Figure of Merit (FOM). The FOM is a measure of performance applied to collector subassemblies and to collimator subassemblies. Each of the four quadrants is graded on a scale from one to nine with five as nominal. Corresponding quadrants of the collector subassembly and the collimator subassembly are averaged. This average then is the final evaluation for the quadrant under consideration and from it can be found the uniformity that can be expected from the combination in that quadrant. Similarly, each of the other three quadrants are evaluated producing an expected range of uniformity of the entire test plane. (See figure 5-10.)

4.2.4 OPTIMAL BURNER/COLLECTOR REPLACEMENT

Frequently it is necessary to replace a burner/collector subassembly while a test is in progress in the chamber. The collimator remains in place and an appropriate burner/collector must be selected. The FOM can be used to make the selection. By scanning the printout of

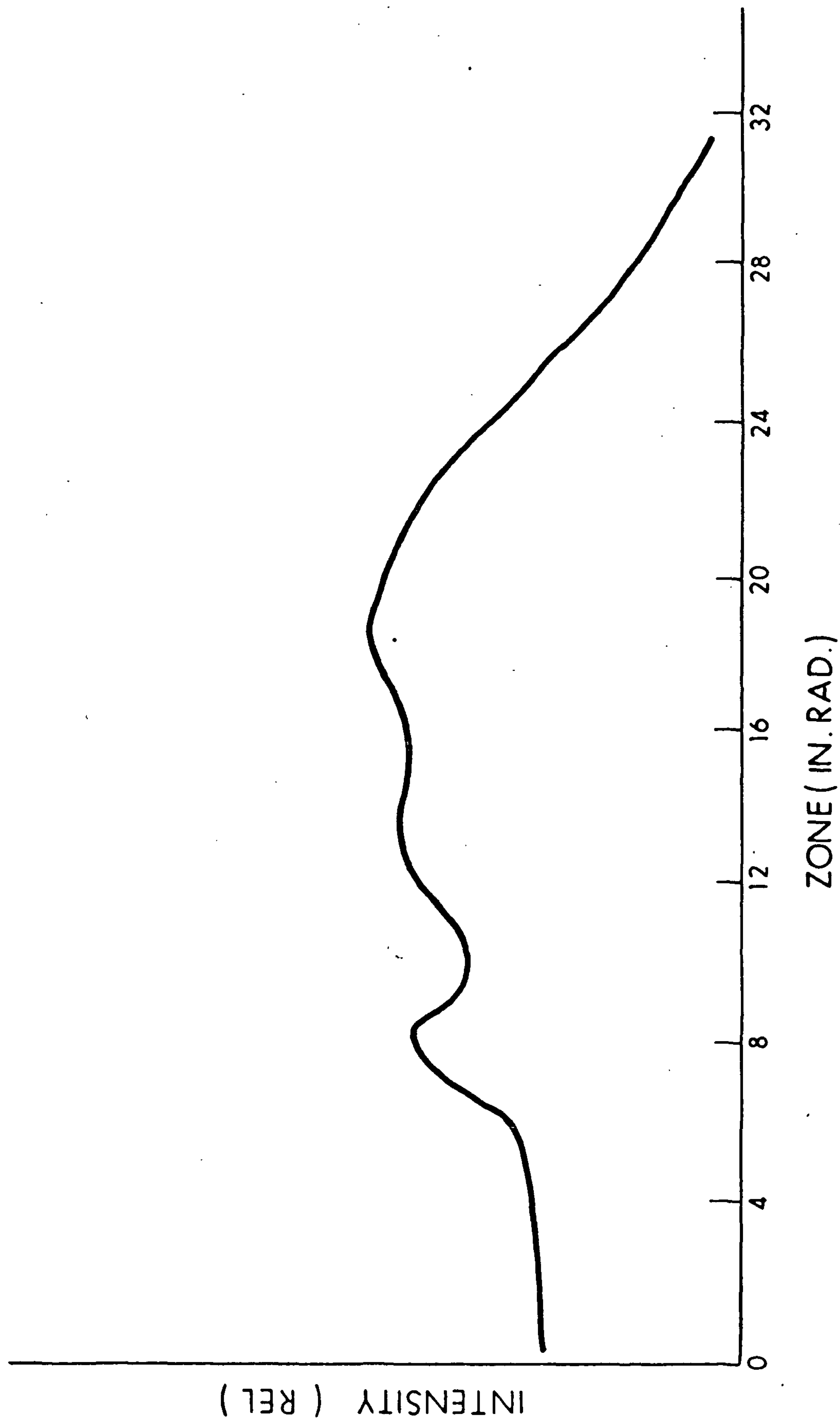


Figure 4-1. Mode 5, Nominal Reflective Optics Collimator Subassembly

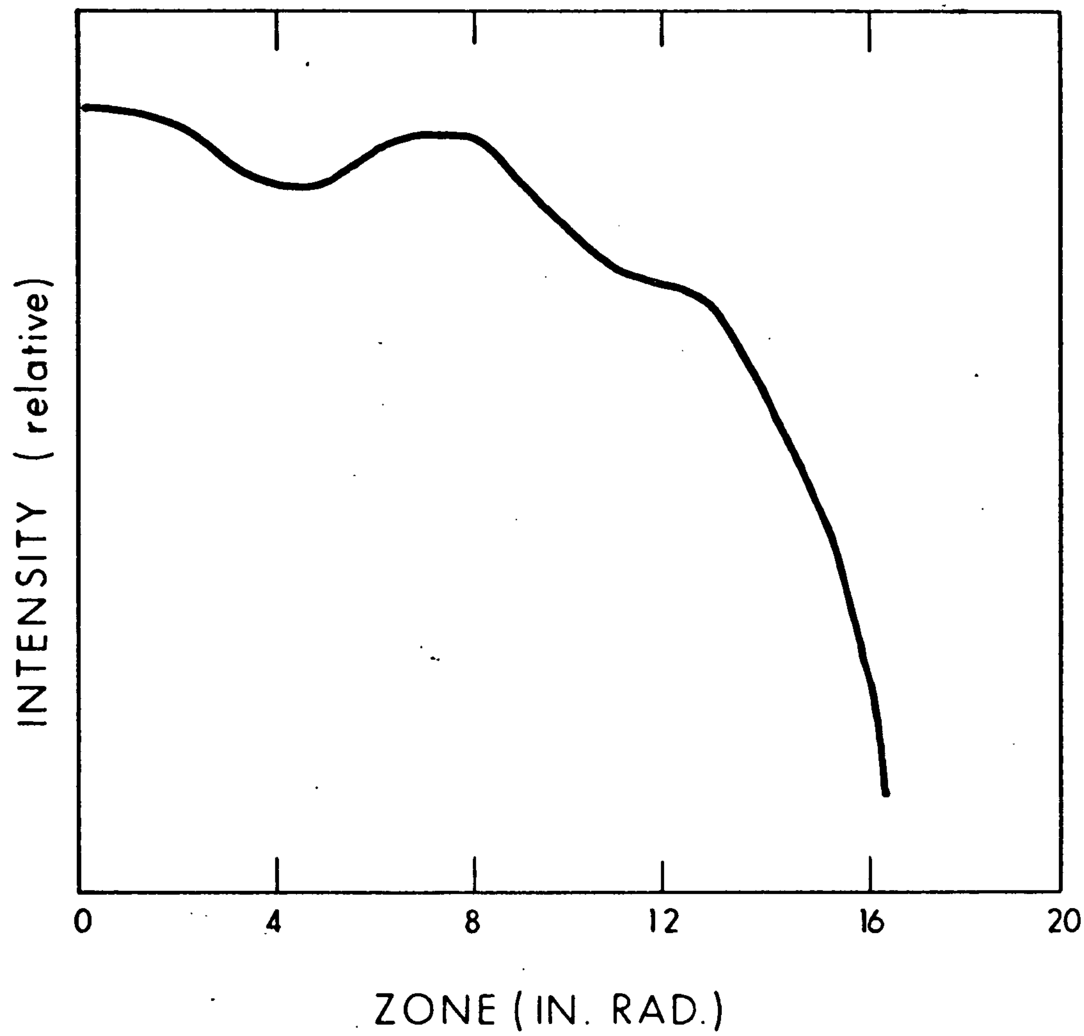


Figure 4-2. Mode 6, Nominal Refractive Optics Collimator Subassembly

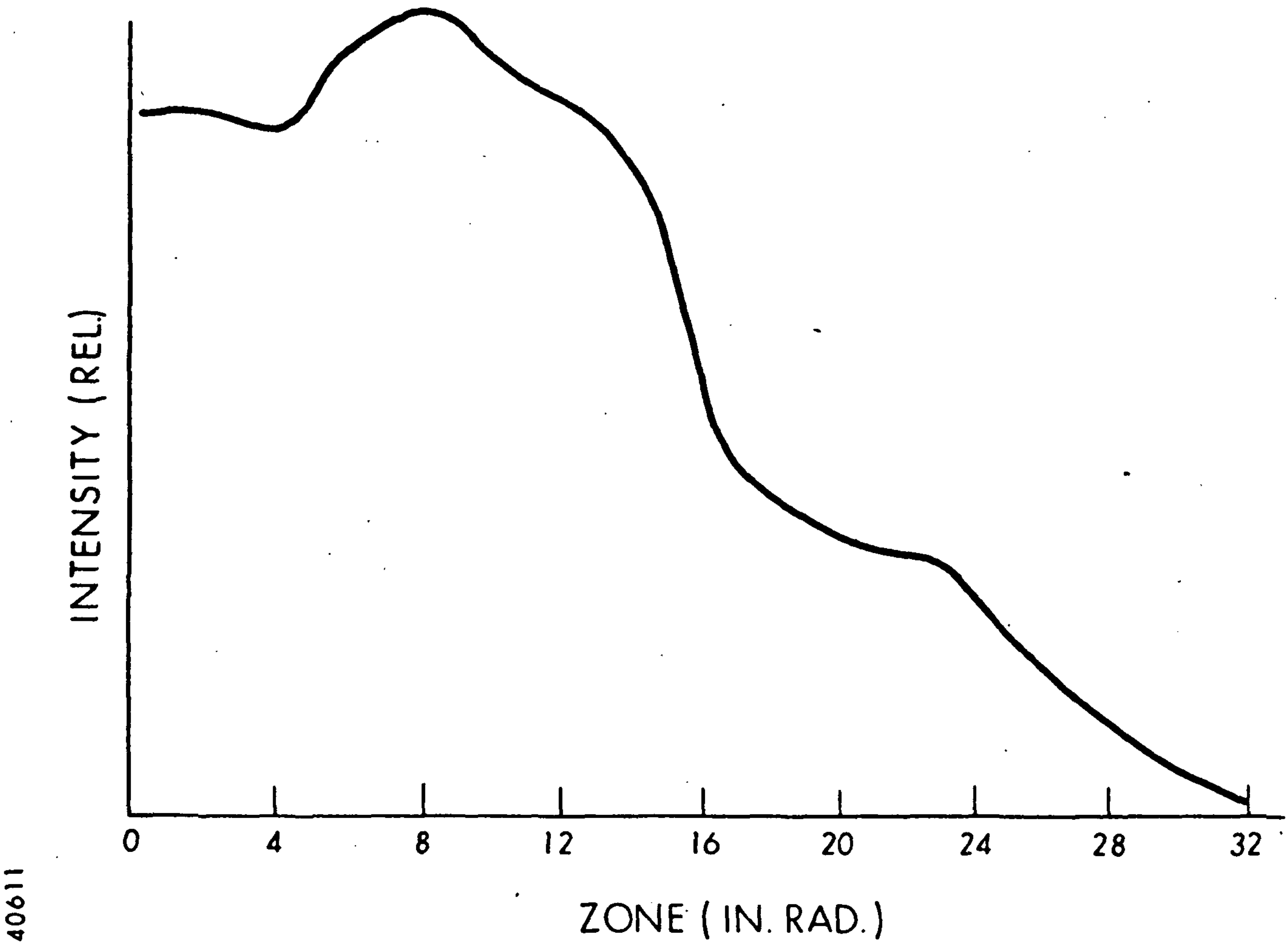


Figure 4-3. Mode 7, Nominal Reflective Plus Refractive Optics Collimator Subassembly

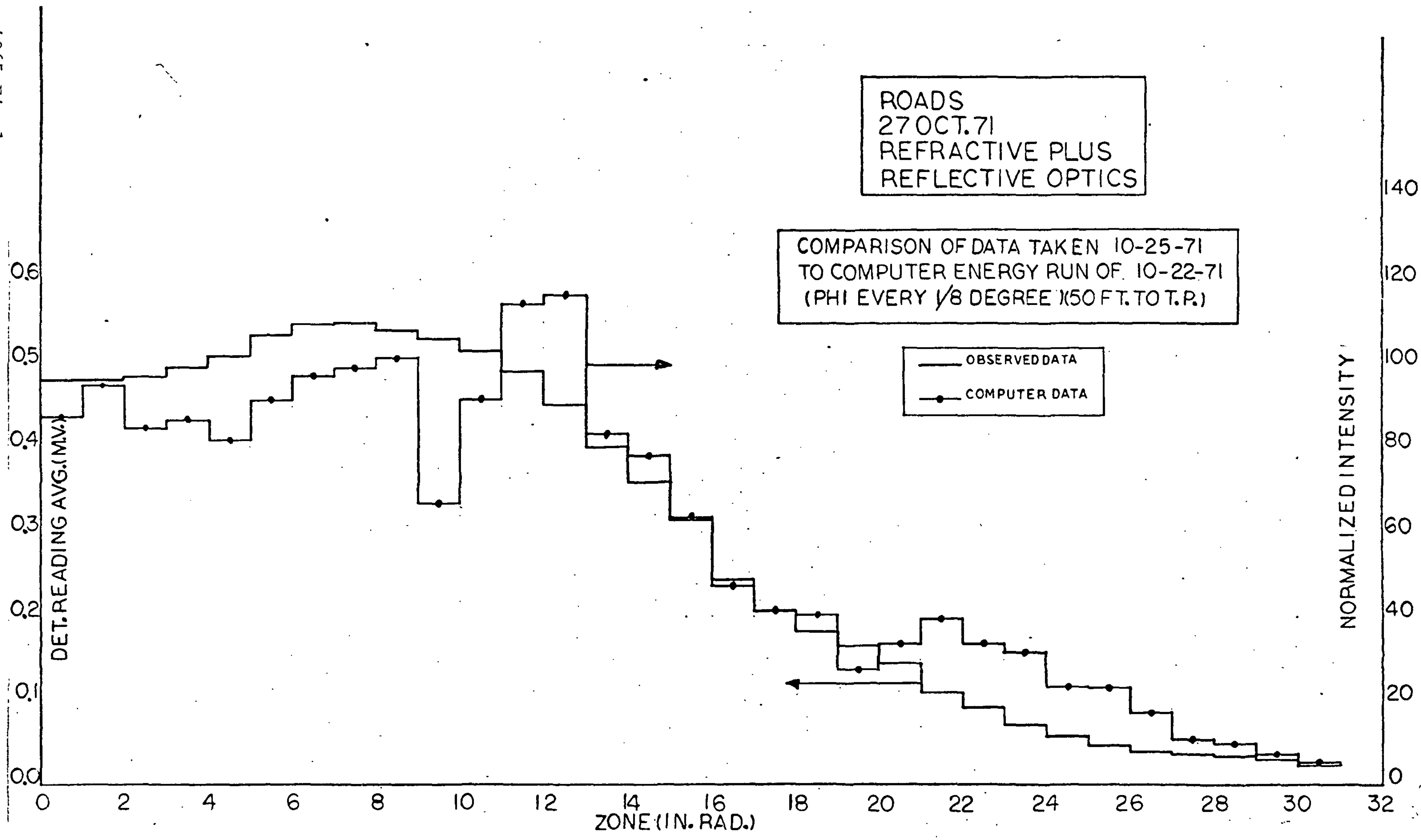


Figure 4-4. ENERGY Measured Data Comparison

collector FOM values in the ROADS Catalog, the operator can quickly compare them to the collimator FOM and limit the choice to a few. These few can then be evaluated individually as to the range of uniformity for the full test plane for the complete module. The entire process will be performed off line and can be accomplished in a matter of minutes without the use of a computer (see figure 5-8).

4.3 ALIGNMENT PROCEDURES

Alignment starts with setting up the optical train to be aligned according to the nominal positions as defined by a current optical layout. The alignment procedures will be basically the same for collector as for collimator. The alignment procedures will end with the alignment of a subassembly and a record of the data associated with it. Nominal intensity curves were discussed in subsection 4.2.2 and a similar curve has been established for each of the subsystems, refractive and reflective, as well as for collector and collimator subassemblies.

The alignment procedures are iterative in nature and can be repeated efficiently many times as a result of the speed of the ROADS system. The alignment procedure consists of two basic analyses-asymmetry and axial. When each subsystem has been aligned, it will be evaluated by analyzing its performance relative to its nominal intensity curve. As an example, consider the collimator subassembly. Before the start of the alignment procedure, all of the components are to be mounted on the test bench as closely as possible to their design positions.

Procedure:

a. Place the douser on the No. 3 mirror in order to work on the refractive system alone. Because lenses with spherical surfaces can be fabricated with a high degree of accuracy, they can be expected to require very little alignment. Just the

same, the output of the refractive system should be scanned using ROADS to check for asymmetry. In the case of the EOS system, the two lenses are fixed in a holder so they cannot be moved relative to one another but the combination can be moved in tandem. If there is significant asymmetry, the alignment guide will point out that it can be due to either tilt or off-axis positioning (x, y displacement). The alignment guide will clue the operator as to what to look for. When the appropriate adjustments have been made, the refractive system output is again scanned for asymmetry and the necessary adjustments made. This iterative procedure is continued until minimum asymmetry has been attained. When the asymmetry has been minimized, the operator will go to the next step.

b. The refractive system should then be scanned for axial alignment. When this parameter is optimized, the CRT display should be checked for asymmetry to be sure that it was not degraded by axial alignment. If so, repeat the procedure starting at a.

   If the refractive system is good in asymmetry and axial alignment, it should show a satisfactory deviation from the nominal. The alignment guide will point out how to proceed. If deviation from the nominal cannot be reduced by iteration, proceed to next step.

c. Remove the douser from the No. 3 mirror and place the douser on the No. 3 or the small collimating lens without disturbing the refractive optics just aligned. The system is now ready for the alignment of the reflective optics starting at step a, but with the appropriate douser in place. The same procedure is followed through step b.

d. With both dousers removed the subassemblies performance will be analyzed.

4.4 COMPONENT ACCEPTANCE TESTING

Testing of the No. 3 mirror is by test plate only. This mirror is spherical in contour and test bench testing is not required. There is no advantage to be gained by applying ROADS.

The optical testing of the No. 1 mirror takes about 15 to 20 minutes after the mirror and light source are set up. The percentage of rejects due to failure of the optical test is very low. Application of ROADS to the testing of this mirror would offer no significant advantage over the present test since reducing the time from the present 15 to 20 minutes without an increase in accuracy represents an insignificant advantage. This is true for the No. 2 mirror as well since its test time and percentage of rejects are about the same as the No. 1 mirror.

Testing the No. 4 mirror, from the point in time when it is completely set up requires from 1.5 to 2.0 hours of data reading and recording. The setup consists of placing a small filament light source at the focal point. A modified Hartmann test mask is then set in place and the individual go-no-go areas visually inspected. If any of them is beyond the minimum or maximum limits scribed on the test bar, the mirror is rejected. A reading is recorded for each test point and many meridians are tested.

If, instead of the small filament lamp, a 5000 watt xenon (or quartz-iodide) lamp were placed at the focal point, a beam would result which could be scanned by the ROADS scanner. The mirror has a diameter varying from approximately 40 to 46 inches. Assuming a nominal diameter of 44 inches, it has a half diameter of 22 inches. The focal point is 35.5 inches from the vertex resulting in a half angle (θ) of approximately 32 degrees. The solid angle (ω) subtended by the mirror is:

$$\omega = 2\pi\ (1-\cos\theta)$$

$$\omega = 0.955\ \text{sr}$$

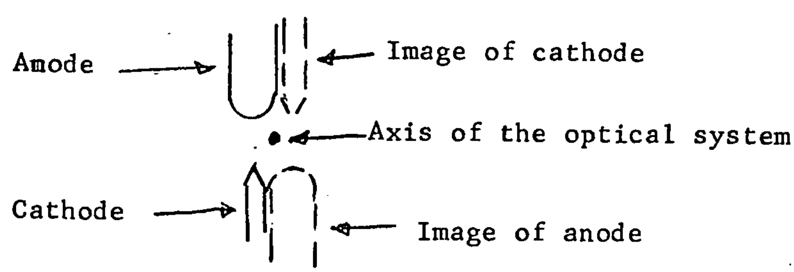
The lamp output is faily evenly distributed over 10 steradians, resulting in an incidence on the mirror of 10 percent of the total energy radiated. The conversion efficiency (radiated energy output/electrical energy input)

is approximately 50 percent. The mirror has a projected surface area of approximately $44^2/144$ or 13 square feet. The system then produces

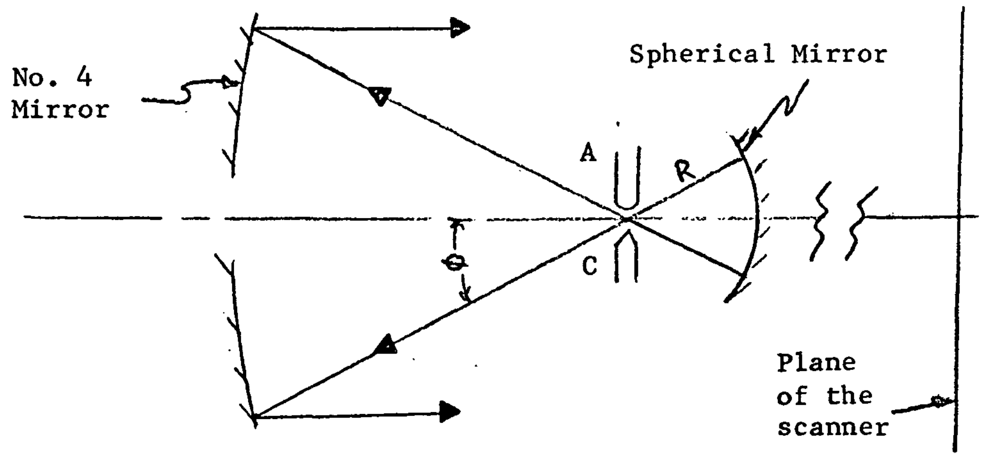
$$\frac{(\text{watts})\ (\eta_{conv})\ (\eta_{incid})}{\text{area}} = \frac{(5000)\ (0.5)\ (0.1)}{13} = 20\ \text{watts/ft}^2$$

on the component test plane located slightly behind the light source. At that level of flux density, the accuracy of the radiometers might be limited. If so, a lens can be mounted immediately above the sensor used to increase the area covered up to five times, thus increasing the energy level at the sensor by a factor of five. This will result in a reasonable energy level (approximately 100 W/ft^2) to be measured.

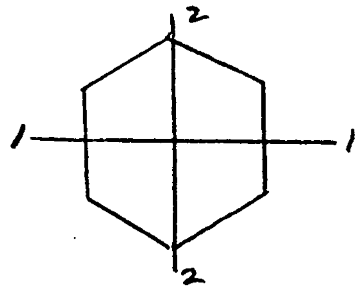
A 5 kW lamp is to be set up in a fixture along with a spherical concave reflector opposite the No. 4 mirror. The center of curvature of the spherical reflector should be nominally positioned a few millimeters from the tip of the cathode on the lamp axis. The lamp should be positioned vertically and with the hot spot (on axis a few millimeters from the tip of the cathode) at the focal point of the No. 4 mirror under test. The center of curvature of the spherical reflector should be offset laterally so that it appears as shown by



This positioning of the spherical reflector maximizes the amount of useful energy from this type of system and minimizes thermal degradation of the anode. Also important for maximizing the amount of useful energy is the subtense of the reflector. The minimum subtense is that which reflects to the points of the hex as shown in the following sketch.

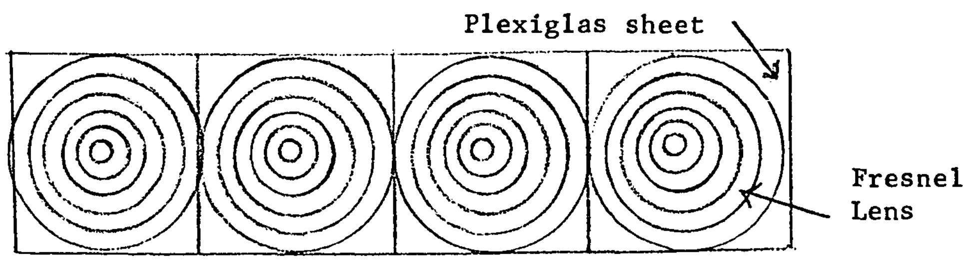


This system should be housed in a water cooled, 10 inch diameter tubing with the appropriate windows (or doors) to provide the proper beam outlet. The cooling should be provided by copper tubing around the outside and a blower inside to cool the lamp. (This fixture could also be used for lamp burn-in.) The scanner, lamp, and No. 4 mirror can be initially aligned to one another with a laser beam. The spherical mirror should be positioned last and as described by the previous sketch. The radius of curvature should be as great as necessary to position it far enough away from the lamp to survive the thermal load (pyrex is recommended). Because of interference by the structure, a 10-inch band will be shadowed. The following shows the two meridians to be run for a complete evaluation:



The test mirror mount must provide the ability to position a mirror in each of these meridians in the horizontal plane (rotation of 90 degrees around the axis). With these two readings all but the central 10-inch square area will be evaluated and most of that is in the central aperture.

As mentioned earlier, by the use of a lens in front of each sensor the level of irradiation can be increased to the approximate level of one solar constant. A Fresnel lens can be used advantageously for this purpose and a typical off-the-shelf lens is shown underlined in figure 4-5. It is thin, lightweight, and breakage resistant. Since the sensors are on 4-inch centers and the outside diameter of this lens is slightly larger than 4 inches, they must be trimmed to 4 inches in four places as shown. These lenses are only 1.6 mm thick and all four should be mounted on a 4 by 16 sheet of ultraviolet filtering Plexiglas as shown in figure 4-6. A plan view would appear,

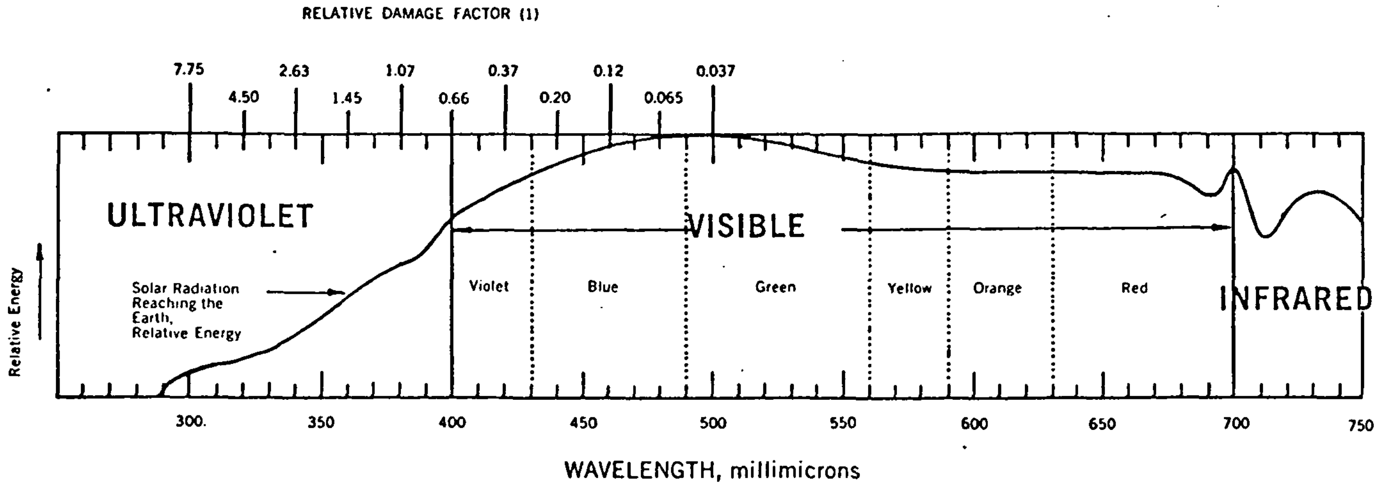


FRESNEL LENSES						
FOCAL LENGTH	CLEAR APERTURE	OUTSIDE DIAMETER	GROOVES PER INCH	THICKNESS	STOCK NUMBER	PRICE
10.2 mm	12.7 mm	38.1 mm	250	1.6 mm	01 LFP 019	$10.00
15.2 mm	25.4 mm	38.1 mm	200	1.6 mm	01 LFP 021	10.00
25.4 mm	25.4 mm	38.1 mm	167	1.6 mm	01 LFP 023	10.00
50.8 mm	50.8 mm	63.5 mm	111	1.6 mm	01 LFP 025	10.00
71.1 mm	101.6 mm	127.0 mm	91	1.6 mm	01 LFP 027	12.00
101.6 mm	101.6 mm	127.0 mm	83	1.6 mm	01 LFP 029	12.00
~~177.8 mm~~	~~127.0 mm~~	~~152.4 mm~~	~~60~~	~~3.2 mm~~	~~01 LFP 033~~	~~16.00~~
203.2 mm	254.0 mm	279.4 mm	52	3.2 mm	01 LFP 035	28.00
317.5 mm	254.0 mm	279.4 mm	43	3.2 mm	01 LFP 037	28.00
317.5 mm	381.0 mm	406.4 mm	125	4.0 mm	01 LFP 039	65.00
609.6 mm	381.0 mm	406.4 mm	125	4.0 mm	01 LFP 041	65.00

OTHER STANDARD FRESNEL OPTICS							
DESCRIPTION	FOCAL LENGTH	CLEAR APERTURE	OUTSIDE DIA.	GROOVES PER INCH	THICKNESS	STOCK NUMBER	PRICE
Negative	-203.2mm	254.0mm	279.4mm	40	3.2mm	01 LFP 043	$28.00
Negative	-317.5mm	381.0mm	406.4mm	36	4.0mm	01 LFP 045	65.00
Dual Focus	177.8+355.6mm	127.0mm	152.4mm	36+72	3.2mm	01 LFP 047	20.00
Cylindrical	76.2	50.8mm	152.4mm	100	3.2mm	01 LFP 049	20.00
Cylindrical	152.4	76.2mm	152.4mm	67	3.2mm	01 LFP 055	20.00
Finite conjugates	*	127.0mm	152.4mm	59	3.2mm	01 LFP 057	20.00
Prism	30Δ**	76.2mm	152.4mm	25	3.2mm	01 LFP 059	20.00

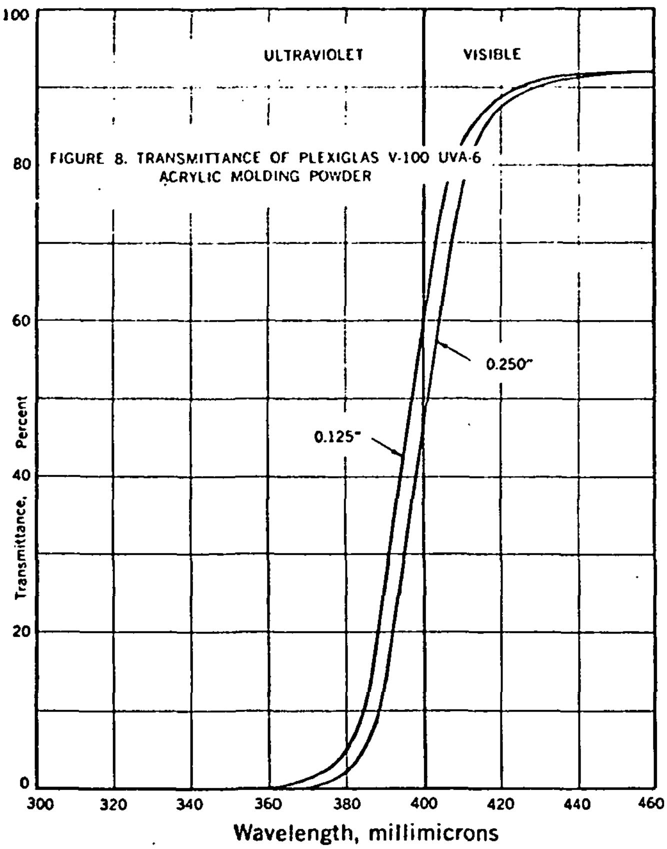
*Corrected for object and image distances of 356 mm.
** Δ = prism diopters; 30Δ = beam deviation of 17° off normal.

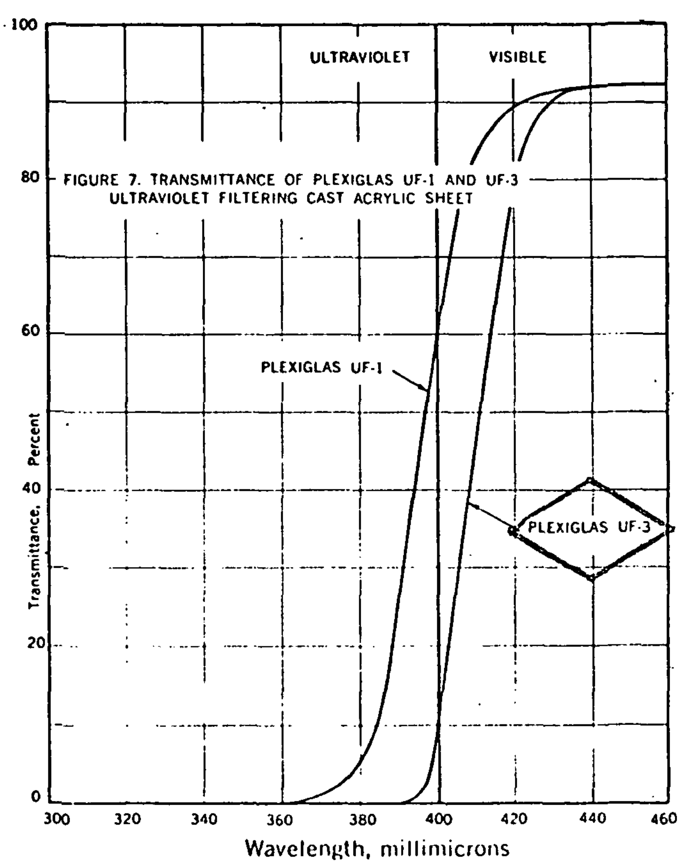
Figure 4-5. Typical Off-the-Shelf Fresnel Lens
(from Optical Industries, Inc.,
1218 East Pomona St., Santa Ana, Calif. 92707)



	FORMULATIONS RECOMMENDED FOR USE IN CLOSE PROXIMITY TO EXHIBITS		FORMULATIONS RECOMMENDED FOR MAXIMUM PROTECTION AGAINST RADIATION DAMAGE	
Physical Form	Cast Sheet	Molding Powder	Cast Sheet	Molding Powder
Name	Plexiglas UF-1	Plexiglas V-100 UVA-6	Plexiglas UF-3	Plexiglas V-100 UVA-7
Suggested Applications	Glazing of picture frames, exhibit cases and protection of exhibits where it is essential that colors of objects must be seen without distortion	Light control lenses	Window, skylight and exhibit case glazing, covers for artificial light sources Glazing for frames to protect objects and documents where the faint yellow tint is not objectionable	Extruded tubing for fluorescent lamp covers
Comments	Colorless; absorbs nearly all ultraviolet radiation	When molded or extruded in a thickness of .125", the spectrophotometric characteristics are the same as those of Plexiglas UF-1	Faint yellow tint; absorbs all ultraviolet radiation and part of the short wavelength violet light	When molded or extruded in a thickness of .060" the spectrophotometric characteristics are the same as those of Plexiglas UF-3

Figure 4-6. Plexiglas Ultraviolet Filtering Formulations





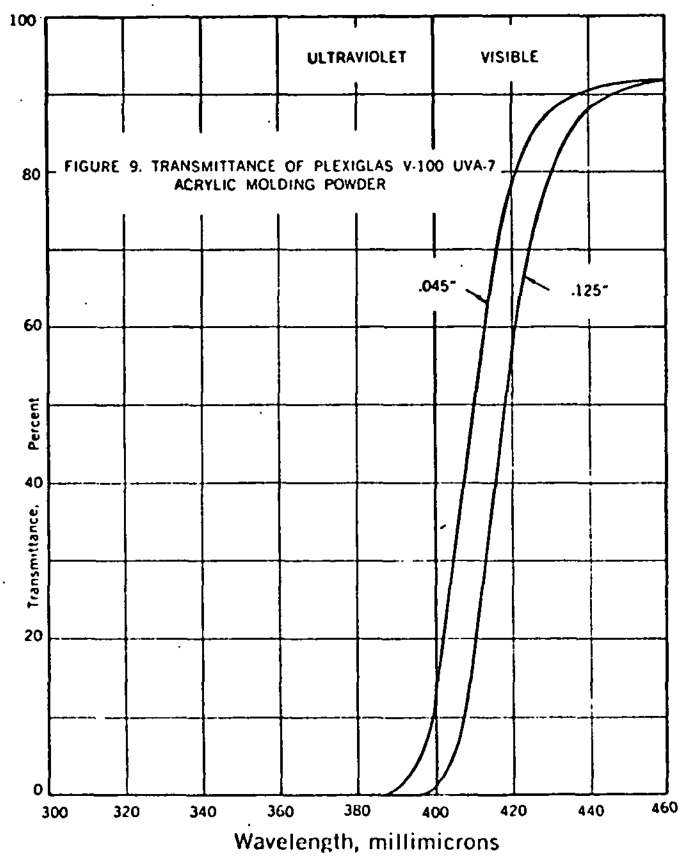
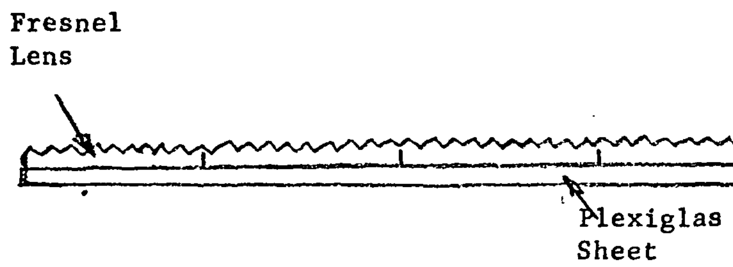


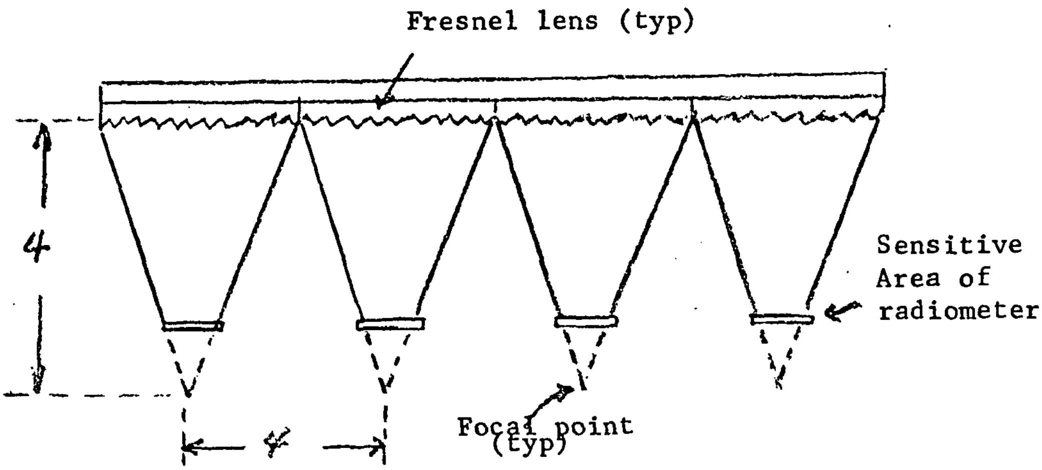
Figure 4-6. Plexiglas Ultraviolet Filtering Formulations (contd)

and an elevation would appear,



The four lens plates should be oriented with the ultraviolet filtering sheet toward the No. 4 mirror to protect the lenses from uv degradation.

The lens plate should be positioned in relation to the sensors so that the beam covers its corresponding sensor. This is accomplished by placing the lens so that the focal point is below the sensor as follows:



The Fresnel lens surface should face the detectors.

The ideal distribution from the No. 4 mirror would be perfect uniformity but this can never be achieved. Once this setup is implemented, mirrors can be measured and the results compared to the results from the present method. A specification can then be established. The readings (54 by 48 inch scan and course configuration) will be evaluated for the following parameters: average, minimum and maximum intensity, uniformity, efficiency, and rms over hex; asymmetry over entire test plane (see Table 5-13).

SECTION 5

SYSTEM DESCRIPTION

The Real-time Optical Alignment and Diagnostic System (ROADS) is a computer-centered system for facilitating the alignment of the modular solar simulation system of the Solar Environment Simulation Laboratory (SESL) at NASA/MSC. ROADS will utilize the acceptance checkout equipment (ACE) which operates in the SESL.

ACE is a computer-controlled system used for spacecraft checkout in either of the two space simulators. Two ACE stations are located in the SESL. Each station consists of two computers with associated peripheral equipment and a number of consoles for monitoring test parameters.

When ROADS is in operation, a complete ACE station will be dedicated to it. The ACE station will be programmed to collect data from the ROADS Alignment Diagnostic Display Console and from the ROADS sensor panel and controller. The collected data will be processed, displayed, and retained by ROADS. Two items of MSC provided hardware which are important components of ROADS are a (Pseudo) Computer Communications START and a Cathode Ray Tube and call-up module. Both units will be used in the alignment area for computer control and data display.

ROADS can be conceptually divided into four major subsystems:

a. Sensor panel and controller
b. Alignment Diagnostic Display Console
c. Data acquisition subsystem
d. Data handling and display subsystem

The sensor panel and controller handle the movement of the sensors. The Alignment Diagnostic Display Console (ADDC) contains status indicators, controls for the sensor panel controller, Cathode Ray Tube and call-up module (CRT), and a Pseudo CSTART. Both the sensor panel and ADDC interface with the data acquisition subsystem. The data acquisition subsystem acquires the sensor reading, positional data, and status information from the sensor panel and the ADDC, and transmits it to the Data Handling and Display Subsystem. This subsystem provides for all processing and displaying of the data. A block diagram showing information flow is given in figure 5-1.

5.1 SENSOR PANEL AND CONTROLLER

The sensor panel is a multiple purpose electromechanical scanner complete with radiometric detectors (see figure 5-2). The scanner is designed to operate in each of the three test areas (see figure 5-3), as well as in each simulation chamber at the MSC. The scanner will include a preprogrammed scanning detector bar using four detectors (Hy-Cal P-8410). The detectors will be manually positioned in a coarse or fine configuration. The coarse configuration places the sensors vertically abreast on 4-inch centers where the sensors' output represents a test plane area of 64 square inches. The fine configuration places the sensors on 1.5 inch centers, vertically abreast, where the sensors' output represents an area of 9 square inches. The diameter of the sensitive area of each sensor is 0.940 inch. The sensitive area of each sensor is 0.695 square inch and for all four sensors yields a sensitive area of 2.78 square inches. The coarse configuration has a coverage of 2.78/64 = 4.35 percent and the fine configuration has a coverage of 2.78/9 = 30.9 percent.

The sensor panel will operate in either of four automatic modes:

a. Limited mode for aligning the collector subassembly.
b. Intermediate mode for aligning the refractive optics of the collimator subassembly.

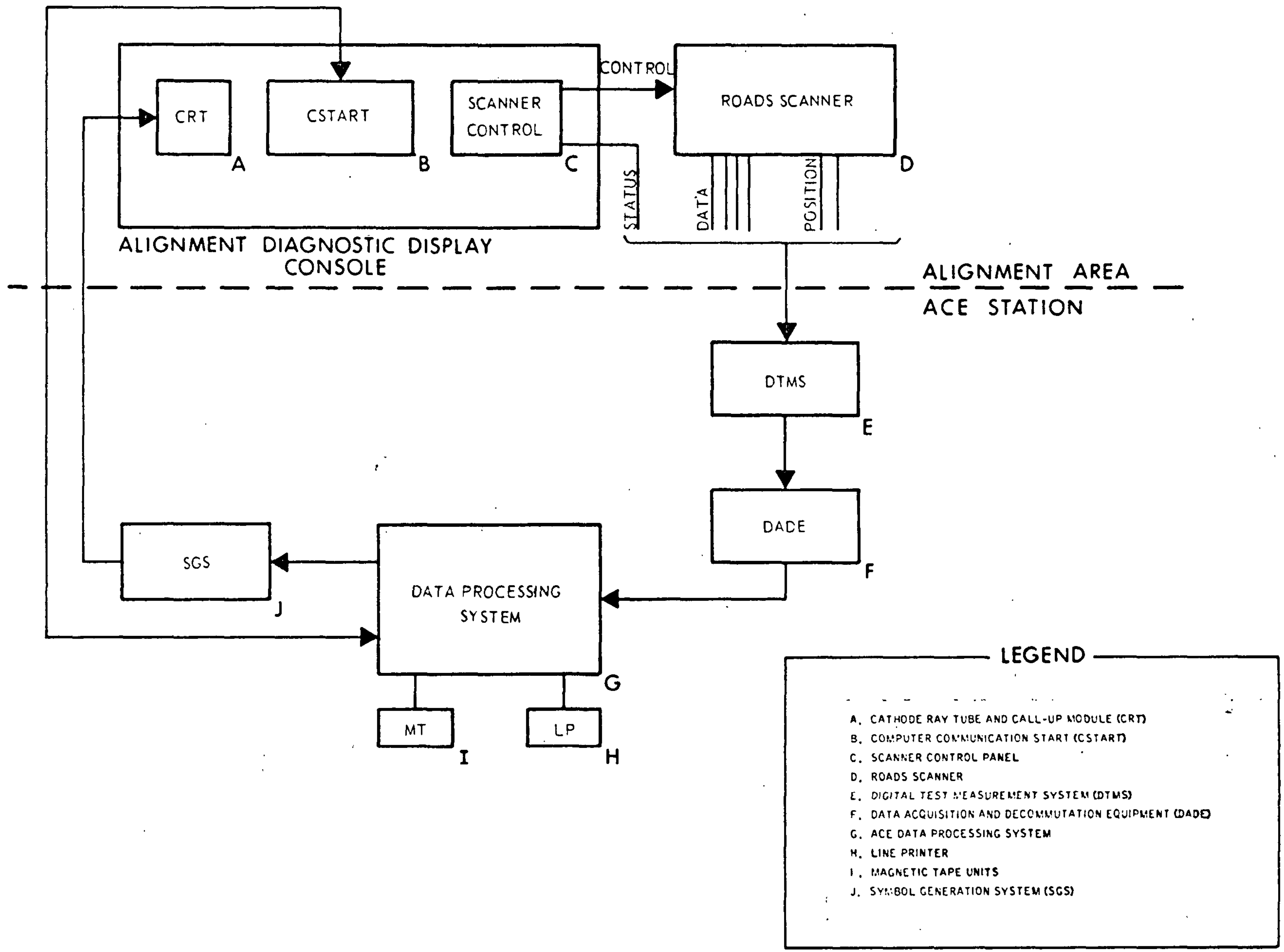


Figure 5-1. ROADS Information Flow

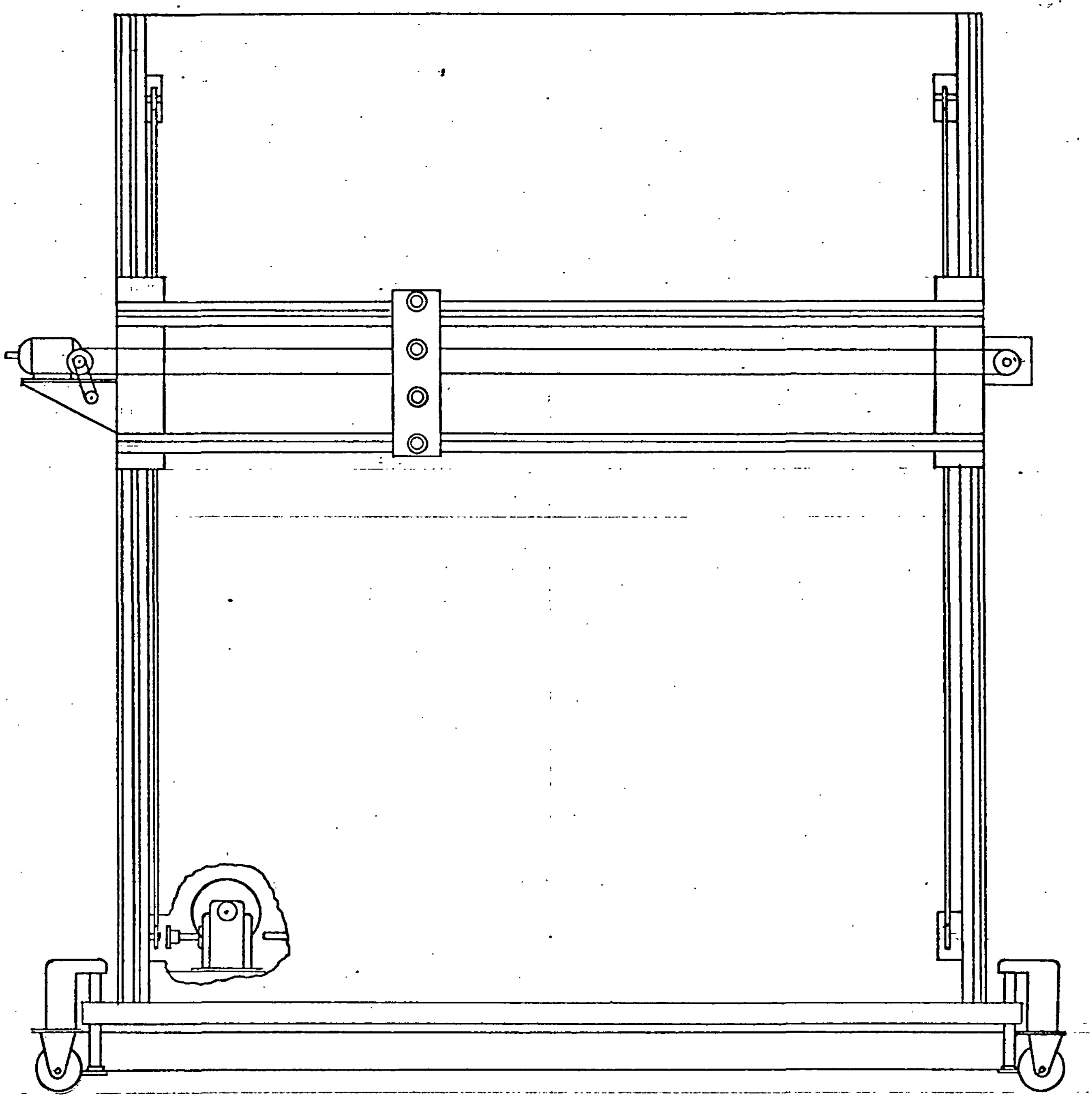


Figure 5-2. ROADS Scanner

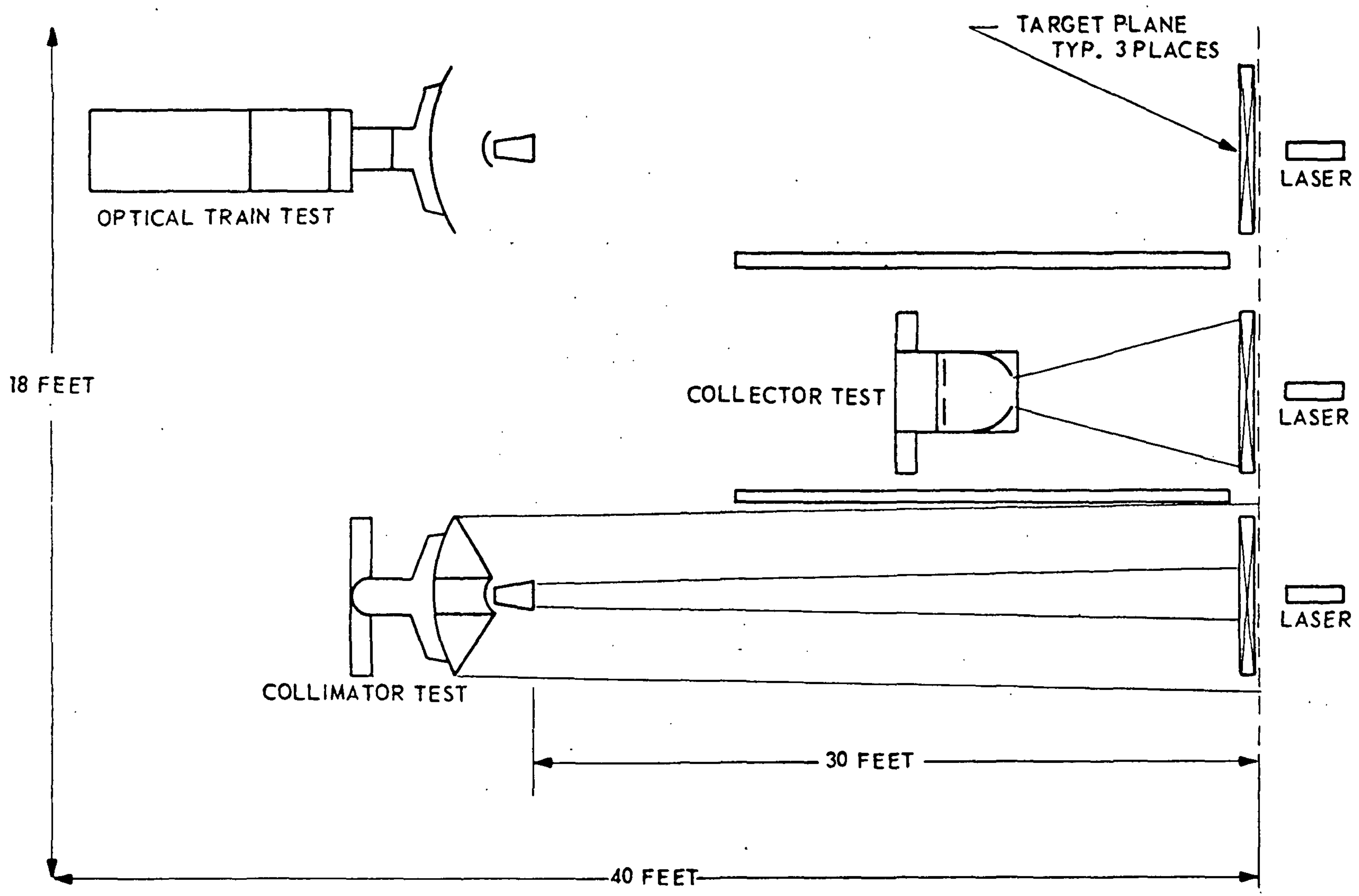


Figure 5-3. Test and Alignment - 3-Channel

c. Full mode for aligning the reflective and full optics of the collimator subassembly and testing of the entire module for the 50-foot throw.

d. Expanded mode for use with the 65 foot throw.

The expanded, full, intermediate, and limited modes will cover areas of approximately 70 inches by 64 inches, 54 inches by 48 inches, 30 inches square, and 12 inches square, respectively (see table 5-1). The four modes will be manually selected. The movement of the sensors in each mode will follow a preprogrammed pattern as shown in table 5-2. The sensor panel and controller have been designed to be easily adaptable to any rectangular scan area with dimensions less than 70 inches by 64 inches.

The speed of travel of the sensors will be selected by the operator from a number of different speeds. Speeds of 1, 2, 3, and 4 inches per second are available. With the 2 inch/second speed and the fine detector configuration, the entire 54-inch by 48-inch test area will be scanned in less than 4 minutes. The smallest test area will be covered in about 90 seconds. Approximate scan times for all test area are listed in table 5-1.

The sensor panel will also operate in a manual mode. In this mode the operator can position the detector bar in any location within the 70-inch by 64-inch scan area. The movement of the detector bar will be controlled by a momentary 4-way switch on the scanner control panel. The switch will control movement in the horizontal or X direction; and in the vertical or Y direction.

The scanner control panel will contain controls for selecting manual or automatic operation, X-Y position control for manual operation, a speed selector, a power switch, and START and RESET buttons. Controls on the scanner panel will also provide selection of detector configuration and automatic scanner mode. Indicator lights will be provided for scanner mode, configuration, scanner ready, and scanning in progress. Table 5-3 lists the scanner characteristics and figure 5-4 illustrates the scanner panel.

TABLE 5-1

SCANNER PARAMETERS

CONFIG.	V. x H. SCANNER MODE	V. x H. NUMBER OF POINTS	V. x H. ACTUAL COVERAGE	V. x H SENSOR BAR TRAV.SIZE	NO. SWEEPS	@1"/SEC TIME (MIN)
1.5	70 x 64	48 x 44	72 x 66	66 x 64.5	12	14.0
1.5	54 x 48	36 x 32	54 x 48	48 x 46.5	9	7.8
1.5	30 x 30	20 x 20	30 x 30	24 x 28.5	5	2.8
1.5	12 x 12	8 x 8	12 x 12	6 x 10.5	2	.5
4.0	54 x 48	16 x 12	64 x 48	48 x 44	4	3.7

(Distance units are inches.)

TABLE 5-1

SCANNER PARAMETERS (contd)

SENSOR CONFIGURATION

1 - Fine = 1.5 inch centers (sensor)

2 - Course = 4.0 inch centers (sensor)

Nominal Size (Scanner Mode)

Test plane to be evaluated (vertical and horizontal dimensions)

Number of Points

Number of points in each dimension in complete scan (vertical and horizontal)

Sensor Coverage

1.5 inch square for fine; 4 inch square for course

Actual Coverage

Length of dimensions measured from first sensor coverage outer edge to last sensor coverage outer edge

Travel Size

Length of dimensions traveled by any point of the sensor bar

Time

Minutes from Start button to end of data acquisition

SCANNER CONFIGURATION

Number of Points	=	$\frac{\text{scanner mode dimension}}{\text{sensor coverage}}$ raised to next even integer for horizontal and next multiple of four for the vertical
Scanner Coverage	=	Number of points x sensor coverage
Number of Sweeps	=	Vertical points/4 raised to next higher integer
Vertical Travel	=	(sweeps -1) (vertical dimension covered by sensor bar)
	=	(sweeps -1) (6) or (sweeps -1) (16) depending on configuration
Horizontal Travel	=	(horizontal points -1) (sensor coverage)
Time	=	(sweeps) (horizontal travel) (ips) + (vertical travel) (ips)

TABLE 5-2

SENSOR POSITIONS FOR DATA COLLECTION

CONFIGURATION	MODE	COORDINATES OF POINTS
1.5	70 x64	X: -32.25" to +32.25" every 1.5"
		Y: -35.25" to +35.25" every 1.5"
1.5	54 x 48	X: -23.25" to +23.25" every 1.5"
		Y: -26.25" to +26.25" every 1.5"
1.5	30 x 30	X,Y: -14.25" to +14.25" every 1.5"
1.5	12 x 12	X,Y: -5.25" to +5.25" every 1.5"
4.0	54 x 48	X: -22" to +22" every 4"
		Y: -30" to +30" every 4"

TABLE 5-3

SCANNER CHARACTERISTICS

<u>Indicator Lights</u>

Scanner Mode: 70 x 64, 54 x 48, 30 x 30, 12 x 12

Detector Configuration: 1.5 or 4 inch centers

Ready: X, Y mode compatibility - coolant flow

Scanning: automatic scan in progress

<u>Controls on Alignment Diagnostic Display Console</u>

Selector: manual or automatic

X, Y position controls (for manual operation)

START, RESET buttons and POWER switch

Speed Selector: 1,2,3, and 4 inches per second

<u>Controls on Scanner</u>

Configuration Selection- 1.5 or 4 inch centers configuration

Scanner Mode Tapes - 70 x 64
54 x 48
30 x 30
12 x 12

<u>Outputs to DTMS</u>

1. Analog - 4 detector outputs (0 - 10 mV)
2. Digital
    a. X, Y position - 8 bits each
    b. run indicator - 1 bit
    c. mode, configuration - 4 bits
    d. speed setting - 2 bits

TABLE 5-3

SCANNER CHARACTERISTICS (contd)

ADDC Output Format

Function	Definition
Run Indicator	0 = Scanner not operative
	1 = Scanner operating
Detector Configuration	0 = 1.5 inch centers
	1 = 4.0 inch centers
Scanner Mode	000 = Manual
	001 = Automatic 54 x 48 inches
	010 = Automatic 30 x 30 inches
	011 = Automatic 12 x 12 inches
	100 = Automatic 70 x 64 inches
Speed Setting	00 = 4 inches per second
	01 = 1 inch per second
	10 = 2 inches per second
	11 = 3 inches per second

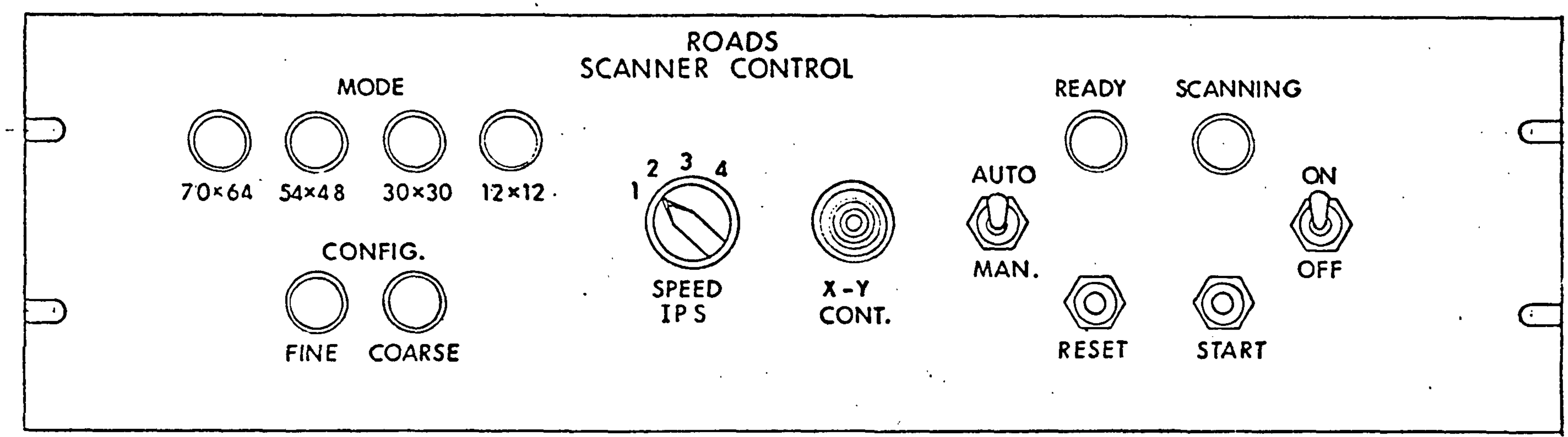


Figure 5-4. Scanner Control Panel

5.1.1 STRUCTURE

The basic structure of the sensor panel consists of a rectangular square tubing frame with a square tubing x cross-member for stiffness. The plane described by the rectangular frame is covered with a water-cooled aluminum panel. The aluminum panel is ¼-inch thick and is laced in a serpentine pattern from the top to the bottom with 3/8 copper tubing for water cooling. The water-cooled aluminum panel is the basic support for a pair of vertical rails, one of which is a ½-inch diameter recirculating ball type slide, the other side being a Z configuration extrusion. On this rail and Z angle extrusion rides a horizontal carriage which has essentially an identical configuration of recirculating ball-screw-rail-and Z extrusion. The four detectors are carried horizontally on this carriage.

The horizontal radiometer bar and the vertical carriage use 1/4-inch and 1/2-inch pitch drive chains. The vertical drive consists of two shafts which are coupled with chains on both sides which carry the horizontal carriage up and down the vertical plane of the panel. The lower shaft is electrically driven with a variable speed shunt-wound motor. A drive motor on the horizontal carriage operates the chain drive for the radiometer bar. The radiometer bar is set up so that the four detectors have multiple positions to provide both the 4-inch spacing and 1½ inch center-to-center spacing. The radiometers have indicators to prevent operating the scanner in the coarse scan mode without having all the radiometers in the coarse mode position. Similar indicators are provided for the fine mode. The water cooling for the panel and radiometers is interlocked with a flow switch to prevent operation of the scanner unless there is water flow.

The water cooled sensor panel is designed to be used with the RIMS independent of the support carriage. The support carriage will be used in the three test ranges and is a wheeled unit which will run between the

three ranges on tracks. The support structure is readily removable to permit easy transfer of the sensor panel from the test and alignment area to the RIMS for use in the space simulation chambers.

5.1.2 MANUAL CONTROLS

Manual controls consist of a selector switch to drive the radiometer bar directly to any point on the panel using the X-Y switch. This is only accomplished when the manual/automatic selector is in the manual position. It is also required that the radiometer bar be placed within the physical dimensions of the mode selected. In other words, if the mode selected is a 12 x 12 pattern, the radiometer bar must be positioned within the 12 x 12 inch square centered around the center of the panel prior to selection of the automatic mode.

5.1.3 AUTOMATIC CONTROLLER

The automatic controller programs automatically the traverse in both the horizontal and vertical directions of the radiometer bar. The system of mechanical limits determines the end positions of the scan in both the horizontal and vertical directions. The scanner is programmed to start in the upper lefthand corner of any of the described mode patterns. It starts and travels to the right until it reaches the limit describing the end of that travel. At that time, it automatically drops the prescribed distance and traverses towards the left. This sequence is

repeated until the complete pattern is covered. At this time, the scanner automatically returns to the start position in the upper left hand corner. The limits are determined by lighted lamps which are sensed by a phototransistor. If the position detector senses a lighted bulb, the circuit logic will command the motor control relays to stop one motor and start the other.

The details of the design of the controller are found in ROADS Scanner Design Package.

5.1.4 OPERATION

This subsection describes only the operation of the scanner, not the use of the computer controls. As was mentioned in earlier paragraphs, the scanner controls consist of a speed control, manual or automatic control, a manual X-Y control for up-and-down and left-and-right, power switch, start button, and reset button. There are also a set of indicators on the control panel indicating the configuration as fine or coarse, the mode,

the fact that the unit is scanning and the fact that the unit is ready to scan. Prior to automatic scanning, the following steps are made:

a. Turn on power;
b. Set the speed selection; either 1, 2, 3, or 4 inches per second;
c. Set for manual control;
d. Manually set the configuration and mode.

The radiometer spacing must match the configuration indicator. If there is water flow through the system the ready indicator will light and the system will operate. Move the radiometer bar to any position inside the selected mode pattern using the X-Y position control, and press reset switch. The radiometer bar will then move to the upper left hand corner of the selected scanner mode. Select automatic operation and press the start switch. The scanner will then scan the selected pattern and return to the reset position automatically. To reset the scanner during a scan, press the reset switch and then restart using the start switch. To shut down the system, at the completion of a run turn off power switch.

5.1.5 OUTPUTS

There are several outputs from the system. These outputs consist of analog outputs from the four detectors and digital outputs from the sensor controller. There are two grey code shaft encoders which give the X-Y position and there will be electrical output to indicate mode, configuration, speed and system operation.

5.1.6 IN CHAMBER USAGE OF ROADS

While the major usage of ROADS will occur with the scanner in the alignment area, a part of the usage will require the scanner to be mounted in either of the two space simulation chambers. When used in either of the

two space simulation chambers the target plane and scanner mechanism will be removed from the scanner base and interfaced with the RIMS transport mechanism. This interface will allow the scanner to be positioned in the chamber to cover any desired area over either of the simulated suns. The usage of the scanner in the chamber will be permitted only when the chamber is not under vacuum.

5.2 ALIGNMENT DIAGNOSTIC DISPLAY CONSOLE

The Alignment Diagnostic Display Console (ADDC) will consist of an electronics rack containing the ROADS scanner control panel, a (Pseudo) Computer Communications START and a Cathode Ray Tube and Call-Up module (see figure 5-5). The scanner control panel was discussed in subsection 5.1. The remaining two items of equipment in the ADDC are provided by MSC and are part of the Data Handling and Display Subsystem. Their use is discussed in subsection 5.4.

5.3 DATA ACQUISITION SUBSYSTEM

5.3.1 STRUCTURE

The Data Acquisition Subsystem includes several ACE systems. This subsystem takes the outputs of the ROADS scanner panel and ROADS Alignment Diagnostic Display Console (ADDC) to the Digital Test Measurement System (DTMS). At the DTMS, the information is conditioned, coverted to digital form, and transmitted in a serial pulse code modulated (PCM) data train to the Data Acquisition and Decommutation Equipment (DADE) which synchronizes to the incoming serial PCM bit stream, decommutates the data, and presents it to the data processing system. A block diagram of this subsystem is shown in figure 5-6.

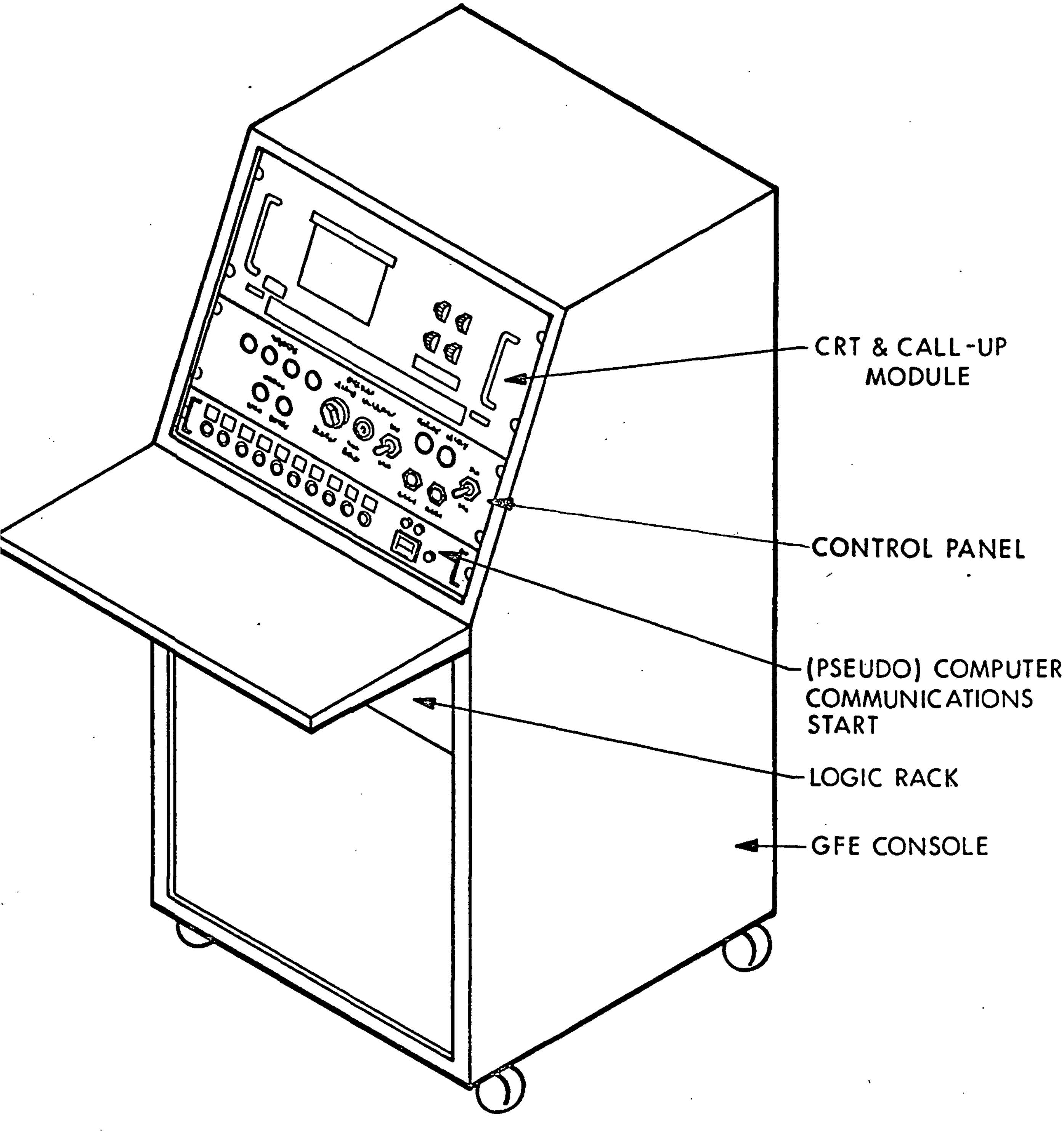


Figure 5-5. Alignment Diagnostic Display Console

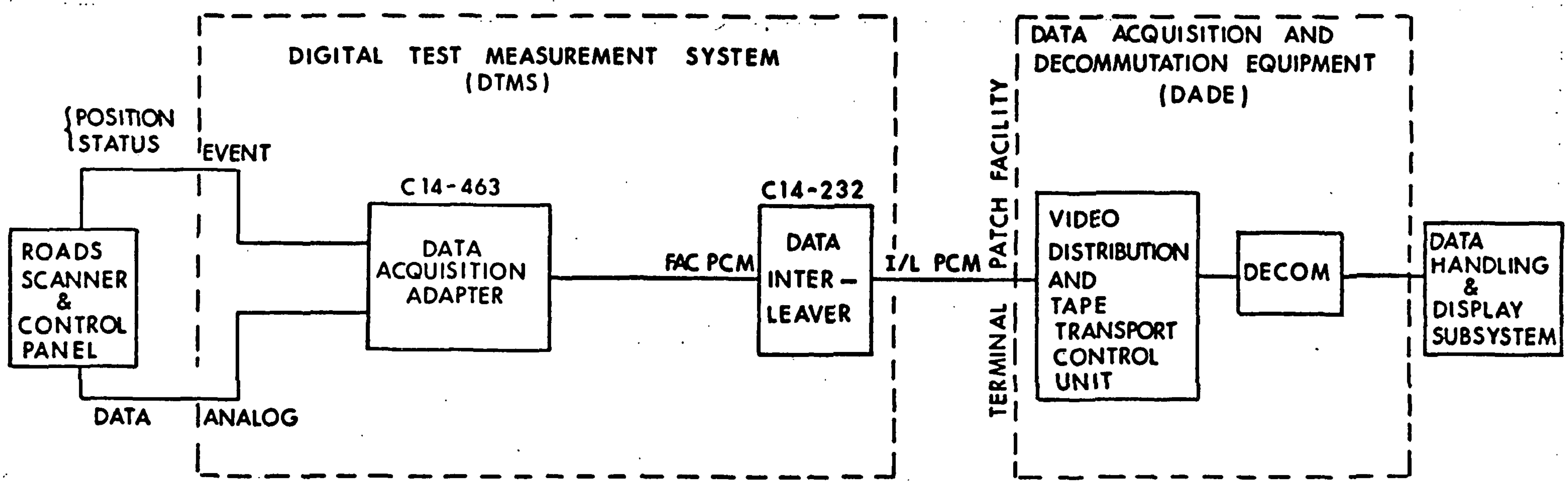


Figure 5-6. ROADS Data Acquisition Subsystem

5.3.2 DATA TRANSMISSION

The required outputs of the ROADS scanner panel and controller will be transmitted using twisted shielded wire pairs which are standard in the ACE. Two-level digital data: (OV or 5V) will consist of the speed setting (2 pairs), mode (3 pairs), detector configuration (1 pair), a run indicator (1 pair) and the X and Y position of the center of the top detector on the detector bar (8 pair each). Continuous analog data will range from 0 to 10 millivolts and will consist of the sensor outputs (4 pair). All information except for the sensor outputs (i.e., all the digital data) will be read as switch closures where the (5V dc) voltage will be applied in the ADDC. The continuous data will be sampled every 20 milliseconds (50 times per second) while the digital data will be sampled every 100 milliseconds (10 times per second).

5.3.3 LIMITATIONS

The accuracy of the data collected from each of the sensors on the ROADS scanner by the Data Acquisition Subsystem is a limitation of ROADS. This accuracy depends on several factors. Since the sensors have an exponential step response function with a time constant of 250 milliseconds, the accuracy of each individual measurement will be a function of the speed at which the sensors are moved. During the initial stages of alignment of a subassembly, the requirements on the accuracy of the sensor data will be less stringent than during the final stages of alignment. Thus during the initial stages of alignment the higher scanner speeds will probably be used with the lower speeds reserved for the final stages of alignment.

Another limitation on the accuracy of the sensor data is the dynamic range of the Digital Test Measurement System (DTMS). The data will be sent from the ROADS scanner over analog lines to the DTMS (a distance of approximately 200 feet) which will digitize the data. The data, which will

probably range from 0 to 10 millivolts (0 to 2 solar constants), will be converted to an eight bit digital word. This means that the quantization error will amount to 40 microvolts (0.01 solar constants).

A third limitation is that of noise entering the analog lines between the sensors themselves and the DTMS. Degradation of the accuracy due to this noise may well overshadow the quantization noise and efforts will need to be made to keep the effect of this noise below that of the quantization noise. Special signal conditioning may be required to accomplish this.

5.4 DATA HANDLING AND DISPLAY SUBSYSTEM

5.4.1 STRUCTURE

The Data Handling and Display Subsystem (DHDS) consists of the ACE data processing system, Symbol Generation and Storage unit (SGS), a (Pseudo) computer communications START module (CSTART), and a Cathode Ray Tube and Callup module (CRT). The ACE data processing system includes the digital computers and associated peripheral equipment. The Symbol Generation and Storage unit (SGS) under the control of the data processing system generates output for the CRT display units. The CSTART and CRT will be part of the ROADS Alignment Diagnostic Display Console (ADDC) which will be normally located in the alignment area (see figures 5-1, 5-4 and 5-7.

Operation of the Data Handling and Display Subsystem will be divided into a number of tasks. Each major function will be a task. Table 5-4 contains a list of the tasks. The initiation of a particular task and input to the DHDS will be controlled using the (Pseudo) CSTART module in the ROADS ADDC in the alignment area. Table 5-5 contains the list of CSTART commands. As can be seen from table 5-5 there are two different types of CSTART commands: input commands and action commands. Input commands will provide parameters to the Downlink (D/L) computer

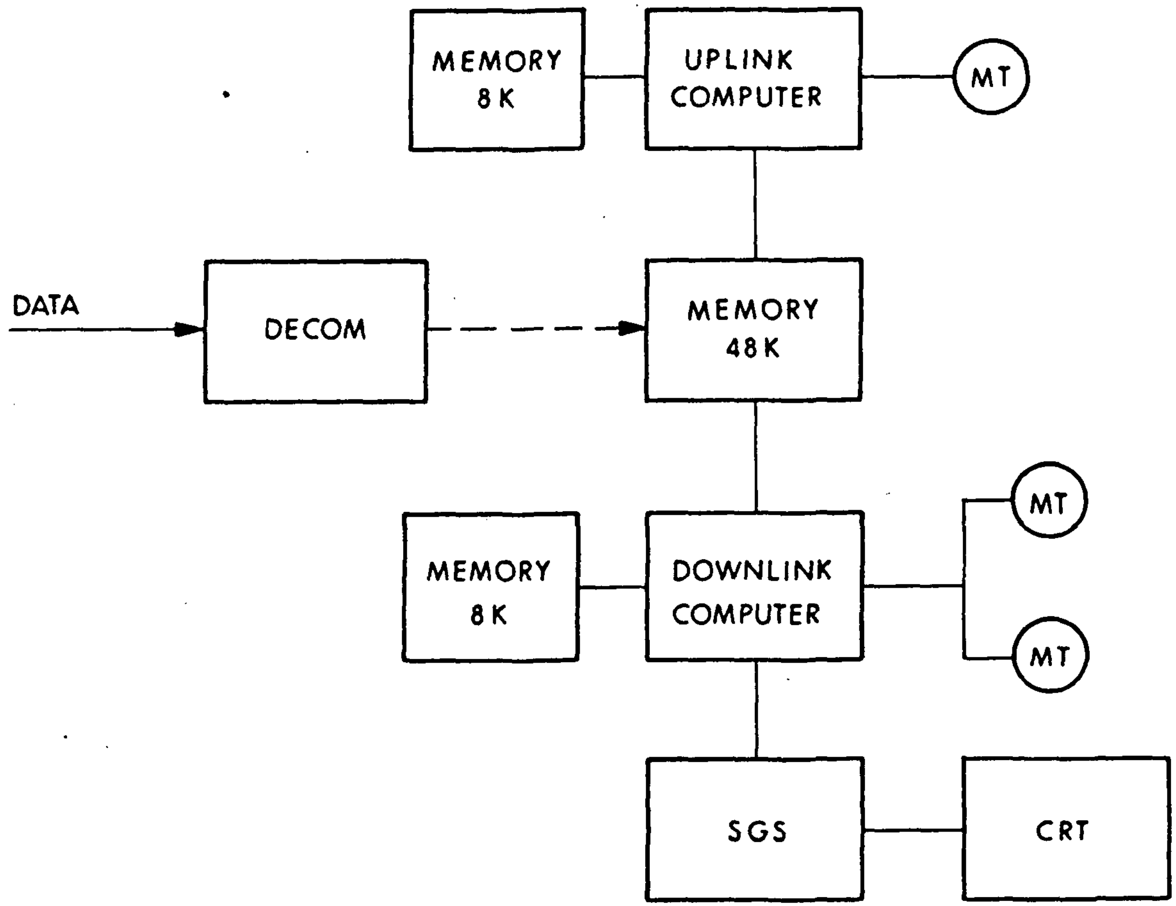


Figure 5-7. ROADS Data Handling and Display Subsystem

TABLE 5-4

DATA HANDLING AND DISPLAY SUBSYSTEM TASKS

Task	Function
1	Collect data from ROADS scanner and generate CRT displays
2	Generate special CRT displays of stored performance data
3	Generate printed display of stored performance data
4	Initialization of Master Data File
5	Add stored performance data to Master Data File
6	Retrieve data from Master Data File
7	Delete unit from Master Data File
8	List summary of the Master Data File
9	Generate plot tape for iso-intensity plotting
10	Predict multimodular performance data

TABLE 5-5

CSTART COMMANDS

COMMAND	TYPE	TASK	FUNCTION
0 0 A B C D E F G H*	input	1	Input unit identification for data collection task
0 1 K N N	action	1	Initiate data collection task for mode NN
0 2 0	action	2	Regenerate performance CRT displays
0 2 1 M	input	2	Change partition-character set to nominal set M
0 2 2 N ± X Y Z	input	2	Change Nth partition level to ± X.YZ solar constants
0 2 3 N C C	input	2	Change Nth character to character number CC (table 5-9)
0 3	action	3	Print unit performance display on line printer
0 5	action	5	Add performance data to master data file
0 6 A B C D E F G H	action	6	Obtain performance data from master data file
0 7 A B C D E F G H	action	7	Delete performance data from master data file
0 8 0 J**	action	8	List summary of master data file on CRT
0 8 1 J	action	8	List summary of master data file on lineprinter
0 8 2 J	action	8	Punch summary of master data file with card punch
0 9 0	action	9	Generate magnetic tape output for iso-intensity plot
1 0 1 K***	action	10	Initiate multimodular prediction task
1 1 A B C D E F G H	input	10	Module number 1 identification for task 10
1 2 A B C D E F G H	input	10	Module number 2 identification for task 10
1 3 A B C D E F G H	input	10	Module number 3 identification for task 10
1 4 T S	input	1	S = Source: S = 0 for C/A, S = 1 for Xenon T = Throw : T = 0 for 50', T = 1 for 65'
1 5 0 0 0 0 0 0 0 0	action	- - -	Abort current task, enter a waiting state

*) ABCDEFGH represents the unit (module or subassembly) identification number

**) J = 0, output data for all units
  1, output data for modules only
  2, output data for collectors only
  3, output data for collimators only

***) K = Orientation of three module array (see 5.4.3)

(e.g., unit ID, partition-character set information, etc.). An input command will not disrupt D/L operation. The purpose of the action command will be to initiate a D/L task. Before initiating the task, however, any on-going task would be aborted. When each task is complete, the DHDS will enter a waiting state until a new CSTART is executed (see figures A-1 and A-2).

One major task of the DHDS is the collection of output from the ROADS scanner panel and controller. This task is currently designated as Task 1. It is controlled using three CSTART commands. One CSTART command determines the four or eight digit unit identification. The identification for each assembly will be a four digit code. When an entire module is being tested, eight digits will be used. The first four will represent the burner-collector subassembly with the remaining four defining the collimator subassembly.

Another CSTART command identifies the source (carbon/arc or Xenon) and the throw (50 feet or 65 feet) for the subassemblies being aligned. This information is used to determine expected performance for the subassemblies being aligned. The third CSTART command contains the data collection/reduction mode and initializes the data collection task (see table 5-6). After this command is executed, the DHDS will indicate confirmation that the command has been received and the task has begun. After this confirmation is received, the operator can start the data acquisition process by depressing the start button on the ROADS ADDC. In addition to starting the preprogrammed sensor movement, this action will start the collection of output from the ROADS scanner and controller. The data processing system receives the data from the DADE.

At the time the start button is depressed, the DHDS will check the consistancy of the scanner setup (i.e., the detector configuration and scanner mode) and the specified data collection/reduction mode. If the setup is not consistant, a message is transmitted to the operator in the

TABLE 5-6

ROADS DATA COLLECTION/REDUCTION MODES (TASK 1)

MODE	ARTICLE	SOURCE	SCANNER MODE	DOUSER	CONFIG	TYPE OF TEST	REFERENCE	OUTPUT UNITS
1	#4 Mirror	Xenon test lamp	54 x 48	- - -	COARSE	Acceptance test	Absolute	LP, CRT
2	Collector - Reflective*	C/A burner	12 x 12	#1 lens	FINE	Subassembly align.	Nominal	LP, CRT
3	Collector - Refractive	C/A burner	12 x 12	#2 mirrors	FINE	Subassembly align.	Nominal	LP, CRT
4	Collector - Full	C/A burner	12 x 12	- - -	FINE	Subassembly align.	Nominal	LP, MT, CRT
5	Collimator-Reflective	Simulated B/C	54 x 48**	#3 lens	FINE	Subassembly align.	Nominal	LP, CRT
6	Collimator-Refractive	Simulated B/C	30 x 30	#3 mirrors	FINE	Subassembly align.	Nominal	LP, CRT
7	Collimator-Full	Simulated B/C	54 x 48**	- - -	FINE	Subassembly align.	Nominal	LP, MT, CRT
8	Module	C/A or Xenon	54 x 48**	- - -	FINE	Module test	Absolute	LP, MT, CRT
9	3 Modules	C/A or Xenon	54 x 48**	- - -	FINE	Multimodular test	Absolute	LP, CRT
0	- - - - -	- - -	Manual	- - -	C/F	Manual	- - -	- - -

*) For Xenon source, modes 2 and 3 will be used.
**) For 65' throw the scanner mode will be 70 x 64

alignment area on CRT page 1 (see figures A-3, A-5, and A-6). The message will explain the problem and instruct the operator to reset the scanner, correct the setup, and restart the scan. If the setup is consistant with the data collection/reduction mode, the data from DADE will be monitored and sampled at appropriate times so that they correspond in position as closely as possible to uniform grid points.

The nominal X-Y positions for the sampled data points can be found in table 5-2. The position readings corresponding to the points where data will be taken from the four detectors can be found in table 5-7. Conversion of the output of each detector from voltage to units of solar constants will be accomplished using separate calibration curves for each sensor. After the sampled sensor outputs are converted to solar constants they will be stored in memory in the performance data buffer for later use. Conversion of the sensor bar position from Grey code to decimal will be accomplished using standard conversion techniques as shown in table 5-8. After the data is collected for the entire scan area, CRT page 2 and in some cases pages 3 through 7 will contain pictorial representations of the collected data, statistics, and indications of misalignment (see subsection 5.4.4 and Appendix B).

When the scanner is being operated manually, Data Collection/Reduction Mode 0 under Task 1 will be used. This mode provides for the display on CRT page 1 of the X and Y position of each detector as well as its output in units of solar constants. This display will be updated once per second. This feature of ROADS is provided to allow detailed study of a few points in the test plane and study of temporal variations in irradiance at a single point. An example of the display generated under this mode can be found in figure B-1.

Task 2 provides broad flexibility in the generation of CRT flux uniformity displays of irradiance data such as is collected by Task 1. Task 2 is controlled by the operator using CSTART commands or by Tasks

TABLE 5-7

SHAFT ENCODER READINGS FOR DATA COLLECTION

Configuration	Mode	Decimal Readings	
1.5	70 x 64	X:	20,25,...,235
		Y:*	25,45,...,245
	54 x 48	X:	50,55,...,205
		Y:	55,75,...,215
	30 x 30	X:	80,85,...,175
		Y:	95,115,135,155,175
	12 x 12	X:	110,115,...,145
		Y:	125,145
4.0	54 x 48	X:	54,68,81,94,108,121, 134,148,161,174,188, 201
		Y:	68,121,174,228

NOTES:
1. Center of the scan area has coordinates (127.5, 127.5)
2. Encoder counts increase when the sensors move from left to right and from bottom to top.
3. A unit encoder count increment represents a movement of 0.3 inches.

*Y position represents that of top (fixed) sensor

TABLE 5-8

GREY CODE - DECIMAL CONVERSION

Gray Code	Binary	Decimal
00000000	00000000	0
00000001	00000001	1
00000011	00000010	2
00000010	00000011	3
00000110	00000100	4
00000111	00000101	5
00000101	00000110	6
00000100	00000111	7
00001100	00001000	8
00001101	00001001	9
00001111	00001010	10
00001110	00001011	11
00001010	00001100	12
00001011	00001101	13
00001001	00001110	14
00001000	00001111	15
00011000	00010000	16
00011001	00010001	17
00011011	00010010	18
00011010	00010011	19
00011110	00010100	20
00011111	00010101	21
00011101	00010110	22
00011100	00010111	23
00010100	00011000	24
etc.	etc.	etc.

1 and 6. The CRT displays are presented using up to six pages of CRT display. This task requires that the data to be displayed reside in the performance data buffer. The displays are based upon using a single coded character (see table 5-9), to represent a particular range (or partition) in the entire range of intensity. Up to five partitions are provided. A partition is defined by its bounds. Each bound except for the first and last is shared by contiguous partitions. Each partition has associated with it a particular character. When the intensity level for a particular element of a display falls within a partition, the associated character is displayed on the CRT screen.

In more mathematical terms, a partition-character set is an ordered sequence of six value-character pairs: (V_1, C_1), (V_2, C_2) ... , (V_6, C_6). V_i is the i-th partition level. C_i is the i-th character. If V is an irradiance value to be displayed using the partition-character (P-C) set above and if C is taken to be the character determined by the P-C set to represent V, then C can be determined as follows:

If $V_i \leq V < V_{i+1}$ for some $i = 1, 2, \ldots, 5$ then

$C = C_i$ else $C = C_6$

The RIMS Solar Uniformity printout uses a similar coding scheme. A detailed description of the display is given in subsection 5.4.4.

Using a CSTART command, "canned" partition-character sets (see table 5-10) can be used or the partition bounds and associated characters can be changed (see table 5-5). In addition, when Task 2 is used by Task 1 or 6, "canned" partition-character sets will be used as a function of the data collection/reduction mode in effect when the data was collected (see table 5-11).

TABLE 5-9

OCTAL CHARACTER NUMBER DEFINITION

BCO Octal Character Display Codes

BCO Octal Code	Character	BCO Octal Code	Character	BCO Octal Code	Character
12	0	43	L	52	% Percent
01	1	44	M	77	° Degree
02	2	45			
03	3	46	O	36	Δ Delta
04	4	47	P	34	θ Theta Caps
05	5	50	Q	17	Ω Omega
06	6	51	R	32	γ Gamma
07	7	22	S	57	μ Mu
10	8	23	T	53	σ Sigma
11	9	24	U	35	ϕ Phi Lower
61	A	25	V	76	ψ Psi
62	B	26	W	37	ω Omega
63	C	27	X	74	λ Lambda
64	D	30	Y	72	∠ Angle
65	E	31	Z	33	, Comma
66	F	60	+	13	* Asterisk
67	G	40	-		
70	H	54	=		
71	I	14	space	55	↑ Arrow
41	J	73	.	56	↓ Arrow
42	K	21	/		

TABLE 5-10

NOMINAL PARTITION - CHARACTER SETS

INDEX	SET 1		SET 2		SET 3		SET 4		SET 5		SET 6		SET 7	
1	1.2	H	1.5	H	1.6	H	.15	H	.3	H	.6	H	2.0	+
2	1.1	+	1.2	+	1.4	+	.1	+	.2	+	.4	+	1.03	0
3	1.05	0	1.1	0	1.2	0	.05	0	.1	0	.2	0	0.97	-
4	.95	-	.9	-	.8	-	-.05	-	-.1	-	-.2	-		
5	.9	L	.8	L	.6	L	-.1	L	-.2	L	-.4	L		
6	.8	X	.5	X	.4	X	-.15	X	-.3	X	-.6	X		

TABLE 5-11

PARTITION - CHARACTER SET ASSIGNMENTS

DATA C/R MODE	P-C SET NUMBER
1	7
2	4
3	4
4	4
5	4
6	4
7	4
8	1
9	1
Multimodular Pred.	1

The different detector configurations and scanner modes required will yield different amounts of collected data to be displayed. All combinations except for the fine detector configuration with the full (54 inch by 48 inch) and expanded (70 inch by 64 inch) scanner modes will result in flux uniformity displays where each measurement is represented by one character on the CRT screen. This display will be on page 2. For the exceptions, six displays will be produced. The display on CRT page 2 will represent the entire test area with only a quarter of the data points being displayed (i.e., every other data point horizontally and vertically). The other views will be the top left, top right, lower left, lower right, and center sections of the test area where each measurement will be represented by a character.

Included in the CRT output will be appropriate qualitative and quantitative measures of the performance of the unit for which the data was taken.

When Task 2 has finished generating the CRT display, the DHDS will normally return to a waiting state. When Task 2 is being used by Task 1, however, control will return to Task 1 (see figures A-5 and A-6).

Task 3 provides for the printing of information similar to that described above under Task 2. The partition-character sets are fixed according to the data collection/reduction mode in effect when the data was collected. One character per sensor measurement will be printed. The output will be produced on the line printer in the computer area. This task is provided to enable hard copy documentation of the final performance of a collector subassembly, collimator subassembly, or complete module. Data Collection/Reduction modes for which this output will be generated are labeled with "LP" in table 5-6.

An important function of the Data Handling and Display Subsystem is the generation and maintenance of a master data file on magnetic tape. This file will contain performance data for each of the subassemblies aligned using ROADS as well as modules if tested by ROADS. The information for each subassembly or module which is stored in the master data file will be in one logical record and is listed in table 5-12.

The data will be in the form of absolute intensity measurements or residuals from a nominal irradiance surface in solar constants depending on the data collection/reduction mode. The position of the data within the record, scanner mode, and detector configuration will serve to define the X-Y position on the test plane associated with each measurement. The record for a particular unit will be uniquely designated by its unit identification.

Tasks 4 through 8 are directly concerned with handling the master data file. Task 4 will probably be the only task not controlled by a CSTART command. It will probably be an off-line task under ROADS due to the amount of input information required. Task 4 handles the initialization

TABLE 5-12

PERFORMANCE DATA BUFFER/MASTER DATA FILE RECORD CONTENTS

ITEM	NO. OF WDS
Unit ID (8 chr)	4
Data collection/reduction mode	1
Scanner mode	1
Detector configuration	1
Speed	1
Date of data collection (8 chr)	4
Source (C/A or XENON)	1
Quantitative performance measures	10*
Qualitative performance measures	4
Collected data	2112*
TOTAL	2139*

*Upper bound

of the master data file. Under the control of off-line (probably) card input, Task 4 will be able to initialize a master data file by either; (1) creating a void master data file tape, or (2) extracting certain records from a previous master data file and creating a new master data file tape containing only those records. The latter capability may be used when preparations are being made for a new spacecraft test and certain of the modules or subassemblies do not require realignment. When this is the case, the latter option will allow the generation of a master data file with data for these units retained from the previous master data file. (See figure A-9.)

Stored information representing the final performance data for a particular subassembly or module will be added to the master data file using Task 5. Task 5 assumes that the data to be stored has previously been

collected by ROADS and resides in memory in the performance data buffer. The task is initiated using a single CSTART command. When the task is complete, the DHDS will return to a waiting state. (See figure A-10.)

Data retrieval from the master data file is accomplished by Task 6. A single CSTART command containing the unit identification will be used to initiate the task. If the required unit is not on the master data file, a suitable indication will be given to the operator, the task will be aborted, and the DHDS will return to the waiting state. If data for the required unit are found, they are stored in memory in the performance data buffer, standard CRT displays are generated and the DHDS returns to the waiting state. With the data in the performance data buffer, particular CRT displays or printed output can be generated. (See figure A-11.)

The deletion from the master data file of the performance data for a particular unit will be accomplished by Task 7. This task will only be used to make minor deletions to the file. Major deletions can be made using Task 4. Task 7 will copy the master data file except for the unit to be deleted to a scratch tape. The scratch tape will then be copied back to the tape being used for the master data file. When this process is complete, the DHDS will return to the waiting state. (See figure A-12.)

A summary of the contents of the master data file is generated by Task 8. This task is initiated by a CSTART command. A digit in the CSTART command word serves to designate whether the summary is to appear on the CRT, to be printed on the line printer, or punched with the card punch. The summary will consist of a tabular output with one line representing each unit: collector, collimator, or complete module. (See figure A-13.) An example of this output is given in figure 5-8.

This summary of the master data file will provide several things; (1) a means to determine which units have been aligned and thus which assemblies have not been aligned, (2) a means of reviewing the performance of each of

UNIT ID	AVE	MIN	(X,Y)	MAX	(X,Y)	RMS	ASYM	THETA	EFF	FOM
ABCDEFGH	±X.XX	±X.XX	(XX,XX)	±X.XX	(XX,XX)	±X.XXX	±.XX/±.XX	XXX	XXX	XXXX

a. Line Printer and Card Format

UNIT ID	AVE	ASYM	THETA	FOM
ABCDEFGH	±X.XX	±.XX/±.XX	XXX	XXXX

b. CRT Output Format

Figure 5-8. Task 8 Output Format

the aligned assemblies, and (3) when all the assemblies have been aligned, a listing of performance parameters for each assembly. This latter listing will be used in optimally placing the assemblies in the side or top sun, optimally replacing a burner/collector, and predicting the combined performance of particular collector - collimator pairs. Items (1) and (2) above will usually require the CRT or lineprinter output. Item (3) will require lineprinter output and perhaps card output. The card output could be sorted according to certain of the performance measures for a relative evaluation of each of the assemblies.

It is considered desirable to obtain an iso-intensity plot on 30-inch paper (or equivalent) to document the final irradiance distribution for a full module. By an iso-intensity plot is meant a plot of the scan area with closed curves denoting specific irradiance levels. The type of plotting equipment required for iso-intensity plots is not available in the ACE. This type of equipment is, however, usually available along with appropriate plotting programs at larger scientific computer installations. These programs generally take their input data from a suitably formatted magnetic tape. It is assumed that such plotting capability exists at the larger computer facilities of the Computation and Analysis Division of MSC.

Task 9 will serve to generate magnetic tape output for use in generating iso-intensity plots. This task., under the control of a CSTART command, will suitably process the data in the performance data buffer and generate a properly formatted magnetic tape. This magnetic tape would be taken to the Data Reduction Center at MSC for final processing. (See figure A-14.)

The availability of this capability and the required format for the magnetic tape to be generated by ROADS under Task 9 will have to be investigated with personnel at MSC.

Task 10 will handle the prediction of the combined performance of three adjacent modules. This task requires three module identification numbers

to be input using three different CSTART commands. A fourth CSTART command indicates the orientation of the three modules and initiates the task. The task consists of fetching the performance data for each of the modules from the master data file, predicting the combined performance by summing the data in overlapping areas, and displaying the data along with appropriate qualitative and quantitative performance measures on the CRT.

The predicted combined performance data will be stored in the performance data buffer for use by other tasks. When this task is complete, the DHDS will return to a waiting state. (See figure A-15.)

5.4.2 DATA COLLECTION

Data acquired from the scanner and the Alignment Diagnostic Display Console (ADDC) by the Data Acquisition Subsystem (DAS) is presented to the Data Handling and Display Subsystem (DHDS) by the Data Acquisition and Decommutation Equipment (DADE). Included in this data are the position coordinates for the detector bar and the outputs from each of the four detectors. The position coordinates will be sampled by the DAS every 100 milliseconds while the detector outputs will be sampled every 20 milliseconds.

For the DHDS Data Collection/Reduction Task (Task 1), modes one through nine, the X position coordinate of the detector bar will be monitored. (See figure A-5.) At particular values of the X position coordinate, samples of the output of each of the detectors will be taken and stored in the Performance Data Buffer (PDB). The particular values of the X coordinate for which data are taken are determined so that the data taken represents position points on a (near) uniform grid over the test plane. When the fine configuration is used these points will be spaced 1.5 inches apart in both the vertical and horizontal directions. For the course configuration the vertical and horizontal spacing is 4 inches. The proper

values of the position coordinates for the points where data are to be taken have been computed and are given in table 5-7. The detector bar position encoders will be calibrated so that one bit change in the encoder output count is equivalent to a change of 0.3 inches for either position coordinate. The encoders will be synchronized so that for data taken during the fine detector configuration (1.5 inch centers) scans, the uniform grid line will always correspond to an integral encoder output count. Thus, the counts in table 5-7 for the fine configuration are exact.

For the course detector configuration (4-inch centers) the counts in table 5-7 represent the integral encoder output counts closest to the proper position. Taking data at these position values will result in a small position error for the 4-inch configuration.

The order in which data will be collected and retained in the PDB depends on the pattern of movement of the detector bar on the ROADS scanner. The motion of the detector bar will start in the upper left hand corner of the scan area, proceed horizontally to the right until the right bound of the scan area is reached, move vertically down 6 or 16 inches, depending on the detector configuration, move horizontally to the left until the left bound is reached, move vertically down 6 to 16 inches, move horizontally left, etc., until the entire scan area is traversed. This will occur on an integral number (may be odd or even) of horizontal sweeps. For the first horizontal traverse the position encoder output will increase; for the next horizontal traverse it will decrease; etc. Thus with each horizontal sweep the order in which the X position coordinate points are met reverses.

The data collected from the ROADS scanner will be sampled so that the data represents position points as near as possible to a uniform grid. Since a discrete representation (the encoder output) of a continuous variable (the position) is being obtained by a sampled data system (DTMS) which is not synchronized to the detector bar movement, there will be

a difference between the actual position corresponding to the sampled data and that corresponding to the uniform grid. This difference represents a positional error when the data is assumed to lie on a uniform grid. (This assumption is made for most of the ROADS data displays). This error has two sources; (1) the data sampling rate interacting with the speed of the detector bar, and (2) the quantization error in the position encoders. The error related to the sampling rate is predominant with the higher detector bar speeds while the quantization error is fixed and is predominant at the lower detector bar speeds. For the fastest detector bar speed (four inches per second) the error related to the sampling rate amounts to about (4 in./sec) (1/10 sec/sample) ($\frac{1}{2}$) = 0.2 inch. The factor of ($\frac{1}{2}$) results from taking the sample closest to the uniform grid. For the fine detector configuration the quantization error does not occur since the position of the uniform grid lines corresponds to an integral count. For the course configuration, however, the quantization error amounts to (0.3 in./count) ($\frac{1}{2}$) = 0.15 inches.

5.4.3 DATA PROCESSING

The majority of the computational activities of the Data Handling and Display Subsystem (DHDS) are done by DHDS Tasks 1 and 10. Task 1 handles the irradiance data collection and reduction. Task 10 predicts the combined performance of three modules using data for each module. The computational activities for Task 1 include the computation of residuals where applicable and computation of the measures of performance of the unit being aligned or tested (see table 5-13). The computational activities for Task 10 include the prediction of the combined irradiance data, as well as the measures of performance.

The computation done under Task 1 is divided into three stages. The first stage involves computing quantities which depend on the irradiance data as it is found in the performance data buffer (PDB) after it has been collected.

TABLE 5-13

ROADS DATA COLLECTION/REDUCTION MODES
(MODE SPECIFIC PARAMETERS COMPUTED)

Mode 1	Component Acceptance Test - No. 4 Paraboloid Hex Mirror Parameters: Average, minimum, and maximum intensity, uniformity, efficiency, and RMS over hex; asymmetry over entire test plane.
Modes 2, 3, 4	Subassembly Alignment - Collector Parameters: Average, minimum, and maximum residual, RMS, asymmetry, efficiency over the area covered by the field lens.
Modes 5, 6, 7	Subassembly Alignment - Collimator Parameters: Average, minimum, and maximum residual, RMS; efficiency over hex (Modes 5 and 7 only); asymmetry over entire test plane.
Mode 8	Module Test Parameters: Average, minimum, and maximum intensity, asymmetry, efficiency and RMS over hex.
Mode 9	Multimodular Test Parameters: Average, minimum, and maximum intensity, uniformity and RMS over the data to be displayed.

Modes 4 and 7 will have a four digit Figure of Merit.

Modes 2 - 8 will have qualitative comments regarding asymmetry.

Modes 2 - 7 will have qualitative comments regarding axial misalignment.

This data will represent the absolute measured irradiance in units of solar constants. The quantities computed in the first stage are the efficiency and asymmetry measures (see table 5-14 and figure 5-9). The second stage involves transforming the data in the PDB into its final form. It is this transformed data that will be displayed and, where applicable, added to the Master Data File (MDF).

For data collection/reduction modes two through seven (see table 5-6) the transformation involves the computing of the deviation (residual) of the collected data from a precomputed nominal. This computation involves subtracting each data point in the PDB from a corresponding point from the appropriate nominal and replacing the collected data point with this signed difference. Thus after the data in the PDB is transformed, the resulting data in the PDB represents an observed-minus-predicted difference surface. It is this data which is used in the computations in the third stage.

The data for the nominal irradiance surfaces used in the computation of above deviations depend on the data collection/reduction mode (i.e., the unit being aligned or tested) and, in some cases, on the distance of throw (65 feet or 50 feet) and the collector source (C/A or Xenon). The data for each of the nominals to be used is shown in Appendix D. For data collection/reduction modes 1, 8, and 9, the data in the PDB is not transformed. This data is used in the third stage in its absolute form.

The performance measures other than the efficiency and asymmetry measures are computed in the third stage. The measures computed for each of the data collection/reduction modes under Task 1 are listed in table 5-13. Definitions for the terms used in table 5-13 can be found in table 5-14 and figure 5-10. In addition to the quantitative measures, two qualitative measures of performance are determined. These are measures of the

TABLE 5-14

DEFINITION OF PARAMETERS

I. Data reduction modes for which nominal intensity surfaces are used.

RESIDUAL: The signed difference between the measured value of the data and that predicted from a nominal irradiance surface.

RMS: The square root of the sum of the squares of the residuals divided by number of points over a selected area.

AVE: The arithmetic mean of the residuals over a selected area.

MAX (MIN): The maximum (minimum) residual.

II. Data reduction modes for which the absolute measured values are used.

RMS: The square root of the sum of the squares of the deviations from the average measurement divided by number of points. This is the sample standard deviation.

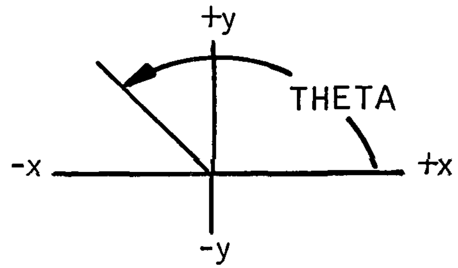
AVE: The arithmetic mean of the measurements over a selected area.

MAX (MIN): The maximum (minimum) measured value in a selected area.

UNIFORMITY: The maximum percentage deviation above and below the average (AVE). (two numbers)

III. Both I and II above.

EFFICIENCY: The percentage of the total measured irradiance falling in the principal area (hex, area covered by field lens, etc.). (See table 5-16.)



NOMINAL OPTIC AXIS IS NORMAL TO
x - y PLANE AND PASSES THROUGH (o - o)

ASYMMETRY CALCULATION

$e_{total} = \sum_{x,y} m(x,y)$ $\quad m(x,y)$ = MEASURED IRRADIANCE AT (x,y)

$e_{+y} = \sum_{y \geq 0} m(x,y) \qquad e_{-y} = \sum_{y \leq 0} m(x,y)$

$e_{+x} = \sum_{x \geq 0} m(x,y) \qquad e_{-x} = \sum_{x \leq 0} m(x,y)$

$\delta_y = (e_{+y} - e_{-y})/e_{total}$ $\quad$ DIFFERENCE BETWEEN % OF ENERGY ABOVE x AXIS AND % BELOW

$\delta_x = (e_{+x} - e_{-x})/e_{total}$

$\theta = \tan^{-1}(\delta y, \delta x) \quad 0 \leq \theta < 360^{o}$

OUTPUT FORMAT: $\quad$ ASYM $= \delta_x/\delta_y$

THETA $= \theta$

QUALITATIVE COMMENT: ASYM = GOOD $\quad$ DETERMINED BY

$\Psi = (\delta_y)^2 + (\delta_x)^2$, A MEASURE OF ASYMMETRY ABOUT (o,o)

$\Psi = o$ IMPLIES THAT ENERGY DISTRIBUTION ABOUT (o,o) IS SYMMETRIC

GIVEN $o < \Psi_1 < \Psi_2 < \Psi_3$

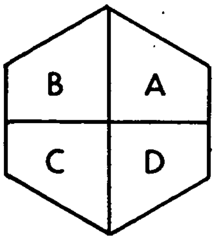
IF $o \leq \Psi \leq \Psi_1$ $\quad$ COMMENT IS ASYM = EXCL

$\Psi_1 < \Psi \leq \Psi_2$ $\quad$ COMMENT IS ASYM = GOOD

$\Psi_2 < \Psi \leq \Psi_3$ $\quad$ COMMENT IS ASYM = FAIR

$\Psi_3 < \Psi$ $\quad$ COMMENT IS ASYM = POOR

Figure 5-9. Coordinate System - Measure Is Inches



QUADRANT · CONVENTION

$$e_A = \frac{1}{N} \sum_{\substack{x > 0 \\ y > 0}} d(x, y) \qquad e_B = \frac{1}{N} \sum_{\substack{x < 0 \\ y > 0}} d(x, y)$$

$$e_C = \frac{1}{N} \sum_{\substack{x < 0 \\ y < 0}} d(x, y) \qquad e_D = \frac{1}{N} \sum_{\substack{x > 0 \\ y < 0}} d(x, y)$$

N is the number of points in the sum

d(x, y) is the deviation from the normal

$$FOM = ABCD$$

Where A, B, C, and D are integers ranging from 1 to 9 and defined as follows:

$$\eta_1 < \eta_2 < \eta_3 < \eta_4 < 0 < \eta_5 < \eta_6 < \eta_7 < \eta_8$$

If $e_A \le \eta_1$ $A = 1$

$\eta_1 < e_A \le \eta_2$ $A = 2$

$\eta_2 < e_A \le \eta_3$ $A = 3$

$\eta_3 < e_A \le \eta_4$ $A = 4$

$\eta_4 < e_A \le \eta_5$ $A = 5$

$\eta_5 < e_A \le \eta_6$ $A = 6$

$\eta_6 < e_A \le \eta_7$ $A = 7$

$\eta_7 < e_A \le \eta_8$ $A = 8$

$\eta_8 < e_A$ $A = 9$

B, C, and D are determined similarly

Figure 5-10. Figure of Merit Calculation

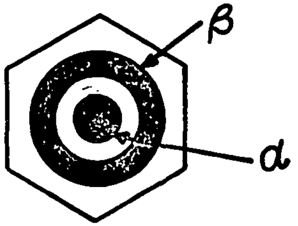
Subscript for η	Boundary for Deviation from Nom.
1	-0.175
2	-0.125
3	-0.075
4	-0.025
5	+0.025
6	+0.075
7	+0.125
8	+0.175

Figure 5-10. Figure of Merit Calculation (cont'd)

axial alignment and asymmetry. The computations involved in the determination of these measures are defined in figures 5-9 and 5-11. A set of parameters are required for determining the qualitative measures. Emperically derived estimates of these parameters can be found in table 5-15. For the determination of the axial alignment qualitative comment two regions must be specified. These regions are labeled in figure 5-11 by the Greek letters alpha and beta. Table 5-16 gives the definition of these regions for each applicable data collection/reduction mode.

The computational activities of Task 10 consist of the prediction of the combined irradiance data of three contiguous modules from data taken from separate testing of each of the modules and the determination of quantitative measures describing the combined performance. The prediction of the combined irradiance data for the three modules involves arithmetically summing overlapping parts of the data for each module as found on the Master Data File. The portions of the performance data for each module which are summed depends on the scanner mode (70" by 64" or 54" by 48") in effect when the module performance data was collected and the position of each module in the 3 module contiguous array. Two different orientations of the three modules are possible. Orientation 0 designates the arrangement where Module 1 is above Modules 2 and 3 which are at the same level (see figure B-36). Orientation 1 designates the arrangement where Modules 1 and 2 are at the same level with Module 3 below (see figure B-37). The overlapping parts of the performance data for each of the modules are defined in table 5-17. The points in table 5-17 are identified as ordered pairs (n, m) where n and m represent, respectively, the row and column containing the data point. This notation is similar to matrix notation where the matrix in this case represents the data points on the test plane.

The prediction of the combined irradiance surface assumes that data for the three modules overlay point for point when the modules are contiguously positioned. This assumption is not true. Assuming it to be true results in no vertical error but a horizontal error of about 1.5 inches in the



$E_\alpha = \frac{1}{N_\alpha} \sum_\alpha d(x,y)$ N_α = NUMBER OF MEASUREMENTS IN REGION α

$d(x,y)$ = DEVIATION FROM NOMINAL AT (x,y)

$E_\beta = \frac{1}{N_\beta} \sum_\beta d(x,y)$ N_β = NUMBER OF MEASUREMENTS IN REGION β

$\Delta = | E_\alpha - E_\beta |$, A MEASURE OF AXIAL ALIGNMENT ERROR

$\Delta = 0$ WILL IMPLY THAT NO AXIAL ALIGNMENT ERROR EXISTS

GIVEN $0 < \Delta_1 < \Delta_2 < \Delta_3$

IF $0 \le \Delta \le \Delta_1$	COMMENT IS	AXIAL = EXCL
$\Delta_1 < \Delta \le \Delta_2$		AXIAL = GOOD
$\Delta_2 < \Delta \le \Delta_3$		AXIAL = FAIR
$\Delta_3 < \Delta$		AXIAL = POOR

Figure 5-11. Axial Calculation

TABLE 5-15

PARAMETERS FOR DETERMINATION OF QUALITATIVE PERFORMANCE MEASURES

Asymmetry - 50 Ft Throw, C/A

Mode	2	3	4	5	6	7	8
ψ_1	0.100	0.020	0.110	0.010	0.001	0.010	0.200
ψ_2	0.200	0.040	0.220	0.020	0.002	0.020	0.280
ψ_3	0.400	0.080	0.440	0.040	0.004	0.040	0.500

Axial Misalignment - 50 Ft Throw, C/A

Mode	2	3	4	5	6	7
Δ_1	0.010	0.001	0.011	0.100	0.050	0.150
Δ_2	0.020	0.002	0.021	0.150	0.100	0.200
Δ_3	0.040	0.004	0.042	0.200	0.150	0.250

Asymmetry - 65 Ft Throw, C/A

Mode	2	3	4	5	6	7	8
ψ_1	0.100	0.020	0.110	0.012	0.001	0.013	0.140
ψ_2	0.200	0.040	0.220	0.024	0.002	0.025	0.260
ψ_3	0.400	0.080	0.440	0.048	0.004	0.050	0.550

Axial Misalignment - 65 Ft, Throw, C/A

Mode	2	3	4	5	6	7
Δ_1	0.010	0.001	0.011	0.110	0.055	0.160
Δ_2	0.020	0.002	0.021	0.175	0.110	0.280
Δ_3	0.040	0.004	0.042	0.220	0.175	0.390

TABLE 5-16

AXIAL ALIGNMENT REGIONS DEFINITION

COLLIMATOR

Alpha (α)						Beta (β)					
30 x 30		54 x 48		70 x 64		30 x 30		54 x 48		70 x 64	
ROW	COLUMN	ROW	COLUMN	ROW	COLUMN	ROW	COLUMN	ROW	COLUMN	ROW	COLUMN
8,13	9-12	13,24	15-18	19,30	21-24	2,19	8-13	5,32	13-20	11,38	19-26
9-12	8-13	14,23	13-20	20,29	19-26	3,18	6-15	6,31	10-23	12,37	16-29
		15,16, 21,22	12-21	21,22 27,28	18-27	4,17	5-16	7,30	9-24	13,36	15-30
		17-20	11-22	23-26	17-28	5,16	4-17	8,29	8-25	14,35	14-31
						6,15	3-8, 13-18	9,28	7-26	15,34	13-32
						7,14	3-6, 15-18	10,27	6-27	16,33	12-33
						8,13	2-6, 15-19	11,26	5-13, 20-28	17,32	11-19, 26-34
						9-12	2-5, 16-19	12,25	4-11, 22-29	18,31	10-17, 28-35
								13,24	4-10, 23-29	19,30	10-16, 29-35
								14,23	4-9, 24-29	20,29	10-15, 30-35
								15,22	3-9, 24-30	21,28	9-15 30-36
								16-21	3-8, 25-30	22-27	9-14 31-36

TABLE 5-16

AXIAL ALIGNMENT REGIONS DEFINITION (contd)

COLLIMATOR

Alpha (α) 12 x 12		Beta (β) 12 x 12	
ROW	COLUMN	ROW	COLUMN
4,5	4,5	3,6	3-6
		4,5	3,6

TABLE 5-16

DEFINITION OF PRINCIPAL AREAS
FOR CALCULATION OF EFFICIENCY

DATA COLLECTION/REDUCTION MODES 2, 3, 4		DATA COLLECTION/REDUCTION MODES 1, 5, 7, 8			
12 x 12		70 x 64		54 x 48	
ROW	COLUMN	ROW	COLUMN	ROW	COLUMN
3,6	4,5	10,39	21-24	4,33	15-18
4,5	3-6	11,38	20-25	5,32	14-19
		12,37	18-27	6,31	12-21
		13,36	16-29	7,30	10-23
		14,35	14-31	8,29	8-25
		15,34	13-32	9,28	7-26
		16,33	11-34	10,27	5-28
		17,32	10-35	11,26	4-29
		18-31	9-36	12-25	3-30

NOTE: Data Collection/Reduction Modes 6 and 9 do not include calculation of efficiency.

TABLE 5-17

MULTIMODULAR PREDICTION MODULE OVERLAP
(Task 10)

Orientation	Scanner Mode	Module	Module Data Points	Corresponding, PDB Points**
0	54 x 48	1	(22,6),(22,27)*	(1,1),(1,22)*
			(36,6),(36,27)	(15,1),(15,22)
		2	(1,20),(1,32)	(3,1),(3,13)
			(22,20),(22,32)	(24,1),(24,13)
		3	(1,1),(1,13)	(3,10),(3,22)
			(22,1),(22,13)	(24,10),(24,22)
	70 x 64	1	(28,12),(28,33)	(1,1),(1,22)
			(48,12),(48,33)	(21,1),(21,22)
		2	(5,26),(5,44)	(1,1),(1,19)
			(28,26),(28,44)	(24,1),(24,19)
		3	(5,1),(5,19)	(1,4),(1,22)
			(28,1),(28,19)	(24,4),(24,22)
1	54 x 48	1	(14,20),(14,32)	(1,1),(1,13)
			(36,20),(36,32)	(23,1),(23,13)
		2	(14,1),(14,13)	(1,10),(1,22)
			(36,1),(36,13)	(23,10),(23,22)
		3	(1,6),(1,27)	(11,1),(11,22)
			(14,6),(14,27)	(24,1),(24,22)
	70 x 64	1	(20,26),(20,44)	(1,1),(1,19)
			(43,26),(43,44)	(24,1),(24,19)
		2	(20,1),(20,19)	(1,4),(1,22)
			(43,1),(43,19)	(24,4),(24,22)
		3	(1,12),(1,33)	(5,1),(5,22)
			(20,12),(20,33)	(24,1),(24,22)

*The four points listed represent corners of the overlapping rectangular array of points.

**For this task the PDB contains a rectangular array of points with 24 rows and 22 columns.

two modules which are at the same level (that is, modules 2 and 3 for orientation 0; 1 and 2 for orientation 1). The error in position of the above mentioned two modules with respect to the third module is about 0.5 inch (see figure 5-12). It is felt that this error is acceptable since similar errors will result when the modules are mounted in the chamber. Thus, the additional system development time and operational computer time required for interpolation to eliminate this error is not warranted.

After the combined irradiance data is predicted, as described above, quantitative performance measures are computed as under data collection/ reduction Mode 9 under Task 1.

5.4.4 DATA DISPLAYS

The irradiance data collected by the Data Handling and Display system can be displayed using the CRT or line printer. The CRT displays are presented using one to six pages of the 20 available CRT pages at one ACE station. The displays are based upon using a single coded character (see table 5-9) to represent a particular range(or partition) in the entire range of intensity. Up to five partitions each with its own character code are provided. When the intensity level for a particular element of the display falls within a partition, the associated character is displayed on the CRT screen. This scheme is discussed more fully in subsection 5.4.1. If the data to be displayed represent measurements taken with the fine detector configuration over the 70 inch by 64 inch or 54 inch by 48 inch scan area, then six views of the area will be provided each on its own page. The views will be the full view where the entire scan area will be represented by a 24 by 22 character array for the 70 inch by 64 inch scan area and by a 18 by 16 character array for the 54 inch by 48 inch scan area, and the top left, top right, lower left, lower right, and middle sections where an approximately 36 inch by 24 inch area will be represented by the 24 by 22

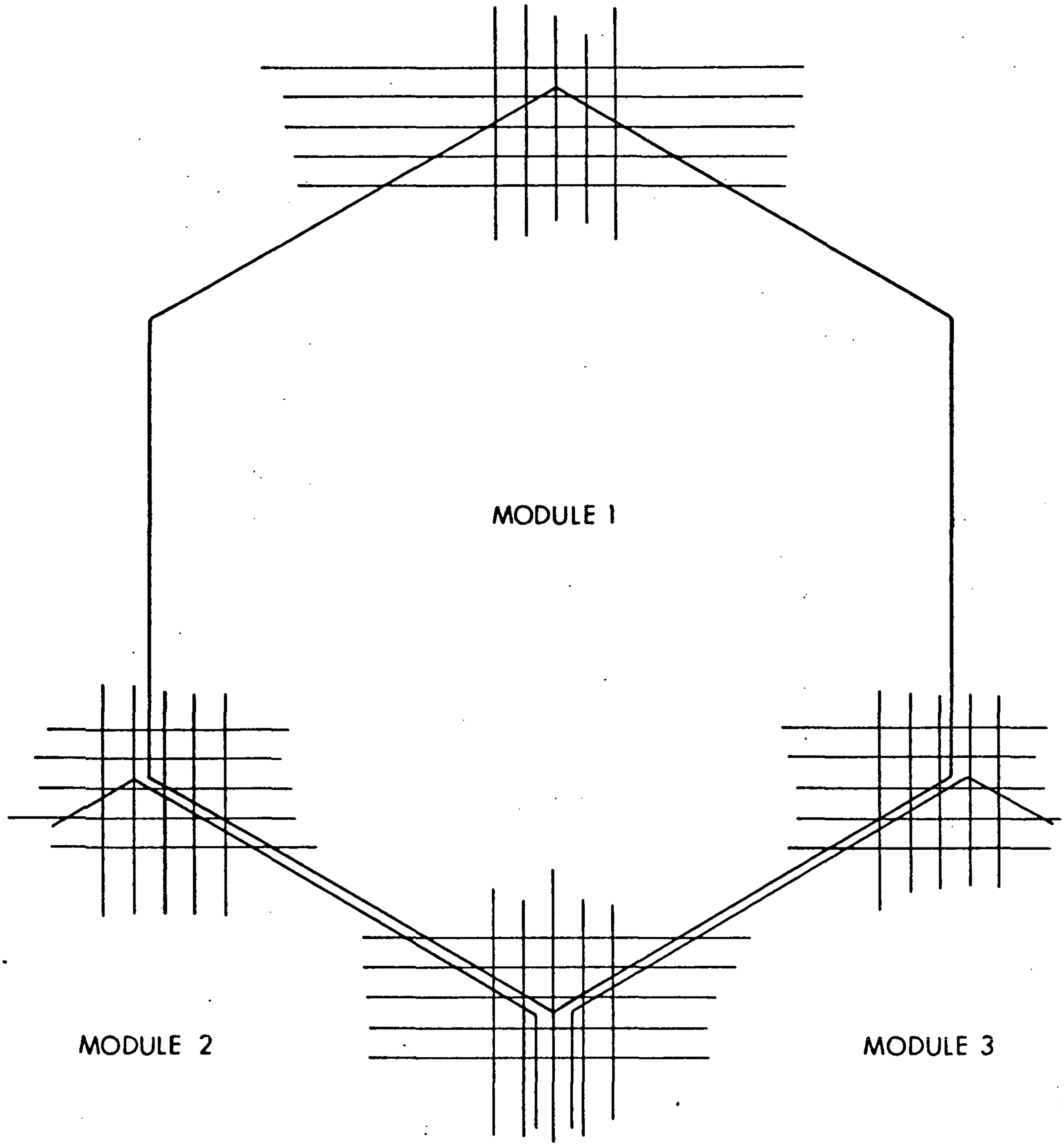


Figure 5-12. Multimodular Prediction Task Position Error
(Orientation 0)

character array. If the data represent measurements over the 30 inch by 30 inch or 12 inch by 12 inch scan area, then only one view is given. This view will be the full view where the 30 inch by 30 inch area will be represented by a 20 by 20 character array and the 12 inch by 12 inch area will be represented by an 8 by 8 character array. Included in each page of the CRT displays will be the unit identification, date, scanner configuration, speed of detector bar, scanner mode, and, where appropriate, the view. Also included will be appropriate qualitative and quantitative measures of performance (see subsection 5.4.3), and a description of the partition-character set used in the generation of the display.

When a single CRT page is sufficient for the display of the irradiance data, page two is used. When the six views are required pages two through seven are used. Table 5-18 gives the CRT pages required for CRT output under DHDS tasks 1, 2, and 10. Examples of each of the CRT displays provided by ROADS are found in Appendix B.

A display similar to that generated on the CRT can be printed on the LP located in the computer area. The partition-character sets used are fixed according to the data collection/reduction mode in effect when the data was collected. For the line printer displays, one character per sensor measurement is printed. This yields a full view of each scan area. Thus, for data collected using the fine detector configuration, the 70 inch by 64 inch scanner mode will yield a 48 x 44 character display, the 54 inch by 48 inch mode will yield a 36 x 32 character display, the 30 inch by 30 inch mode a 20 by 20 character display, and the 12 inch by 12 inch mode an 8 by 8 character display (see table 5-1).

5.4.5 DATA STORAGE AND RETRIEVAL

The Data Handling and Display Subsystem (DHDS) generates and maintains a record of the final performance of subassemblies aligned by ROADS and modules if tested by ROADS. This record is called the Master Data File

TABLE 5-18

CRT PAGE USAGE

DHDS TASK	DATA C/R MODE	CRT PAGES USED
1,2	0	1
	1	1,2
	2	1,2
	3	1,2
	4	1,2
	5	1-7
	6	1,2
	7	1-7
	8	1-7
	9	1,2
10	-	1,2

and resides on magnetic tape. The information contained on the Master Data File for each unit consists of the collected performance data, the determined qualitative and quantitative measures of performance as well as the date the data was taken and other identification information. A more detailed listing of the contents of the master data file is given in table 5-12.

The Master Data File (MDF) is generated and maintained by the DHDS using tasks 4 through 8 (see table 5-4). Initialization of the MDF is accomplished by Task 4. Addition to and deletion from the MDF is handled by Tasks 5 and 7, respectively. Retrieval of data is done using Task 6. The generation and maintenance of the MDF under Tasks 4 through 8 is described in subsection 5.4.1.

5.4.6 OTHER OUTPUT

The Data Handling and Display Subsystem (DHDS) generates several outputs in addition to the CRT and line printer displays of unit performance data mentioned in subsection 5.4.4. One of these outputs is a summary of the contents of the Master Data File (MDF). The summary is either displayed on the CRT using pages 1 through 20, printed on the line printer, or punched with the card punch. The summary will consist of a tabular output with one line representing each unit: collector, collimator, or complete module. An example of this output is given in figure 5-8.

The summary of the master data file will provide several things; (1) a means to determine which units have been aligned and thus which assemblies have not been aligned, (2) a means of reviewing the performance of each of the aligned assemblies, and (3) when all the assemblies have been aligned, a listing of performance parameters for each assembly. This latter listing will be used in optimally placing the assemblies in the side or top sun, optimally replacing a burner/collector and predicting combined performance of particular collector - collimator pairs. Items

(1) and (2) will usually require the CRT or lineprinter output. Item (3) will require lineprinter output and perhaps card output which could be sorted according to certain of the performance measures for a relative evaluation of each of the assemblies.

Another output produced by the DHDS is a magnetic tape for use in the generation of iso-intensity plots of the final irradiance distribution for a module tested by ROADS. An iso-intensity plot is a plot of the entire scan area (54 inch by 48 inch or 70 inch by 64 inch) with closed curves denoting specific irradiance levels. The generation of magnetic tape output for use in generating iso-intensity of plots is accomplished by DHDS Task 9 (see subsection 5.4.1).

5.4.7 LIMITATIONS

Several limitations in the Data Handling and Display Subsystem are evident. One major limitation is the use of an ACE station by ROADS. While the ACE station allows ROADS to have great flexibility in the area of data collection and display generation, it also limits the usefulness of ROADS. Since ROADS requires a dedicated ACE station, ROADS can only operate when an ACE station is available. Spacecraft tests, ACE repair and maintenance, as well as other tasks may all interrupt the alignment process.

Another limitation is the need to produce output in the computer area. The master data file as well as the line printer output will be generated in the computer area, since it is not feasible to have the line printer or a magnetic tape unit in the alignment area. Thus, adequate procedures and controls must be implemented for handling and storing this output.

SECTION 6

SYSTEM USAGE

6.1 UNIT ALIGNMENT AND TESTING

6.1.1 COMPONENT ACCEPTANCE TESTING

As discussed in subsection 4.4, the only component requiring a significant test time (not counting setup time) is the No. 4 mirror. This mirror, which averages 1.5 to 2 hours, is the only component that requires more than the usual 15 to 20 minutes for data gathering and reduction.

6.1.2 COLLIMATOR ALIGNMENT

6.1.2.1 Carbon Arc System

The first consideration in laying out a test bench for aligning the collimator subassembly is whether to use a carbon arc burner/collector or set up a dummy collector. The use of a carbon arc collector would result in nonrepeatable measurements as well as be a difficult system for the operator to manage single-handed. In addition, as the carbon arc burner/collector degrades, eventually requiring replacement, it will be difficult to duplicate accurately. In addition, a dummy collector is more easily modeled by ENERGY. All aspects considered, the dummy collector is the better choice.

Figure 6-1 shows the dummy collector as set up at EOS. The headlight assembly consists of a 14-inch parabola, f.l. = 2.35, and a 2 kW halogen-quartz lamp. It is continuously adjustable axially. The output of the headlight assembly is incident on the 15-inch diameter diffuser (mylar)

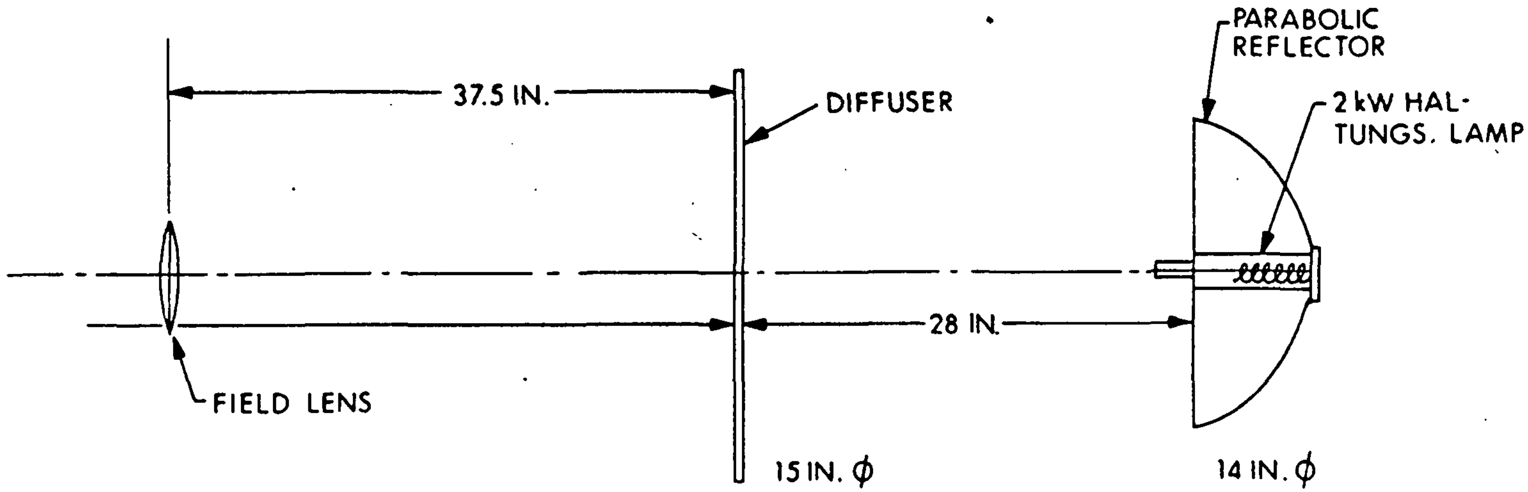


Figure 6-1. Dummy Collector - Schematic

positioned in the plane of the collecting lens. At this position it provides incident energy on the field lens within the same cone angle as provided by a carbon arc burner/collector.

By inputting polar distribution and luminance values for the diffuser, ENERGY computes the distribution for the reflective system, the refractive system, and both systems as indicated on figures 6-2, 6-3, and 6-4. A comparison of the subassembly performance as measured on the EOS test bench compared to the test plane uniformity computed by ENERGY. These results are shown in figure 4-4.

6.1.2.2 Xenon System

The same type of dummy collector will be set up to appear to the field lens as described in subsection 6.1.2.1, but this one will not require the diffuser. A halogen-quartz lamp placed in an actual reflector to be used in the simulator will be recommended for use on this test bench.

6.1.3 COLLECTOR ALIGNMENT

6.1.3.1 Carbon Arc System

The smallest scanning mode is 12 by 12 (1 ft^2) and is to be used for the collector alignment (reflective, refractive, and complete subassembly). The total energy, ϕ, on the 54 by 48 module test plane ($\sim$ 15 ft^2) is

$$\phi = 130 \times 15 = 1950 \text{ W}$$

If the efficiency of the field lens and the collimator subassembly combined is 0.65, the power required from the collector subassembly is

$$\frac{1950}{0.65} = 3000 \text{ W}$$

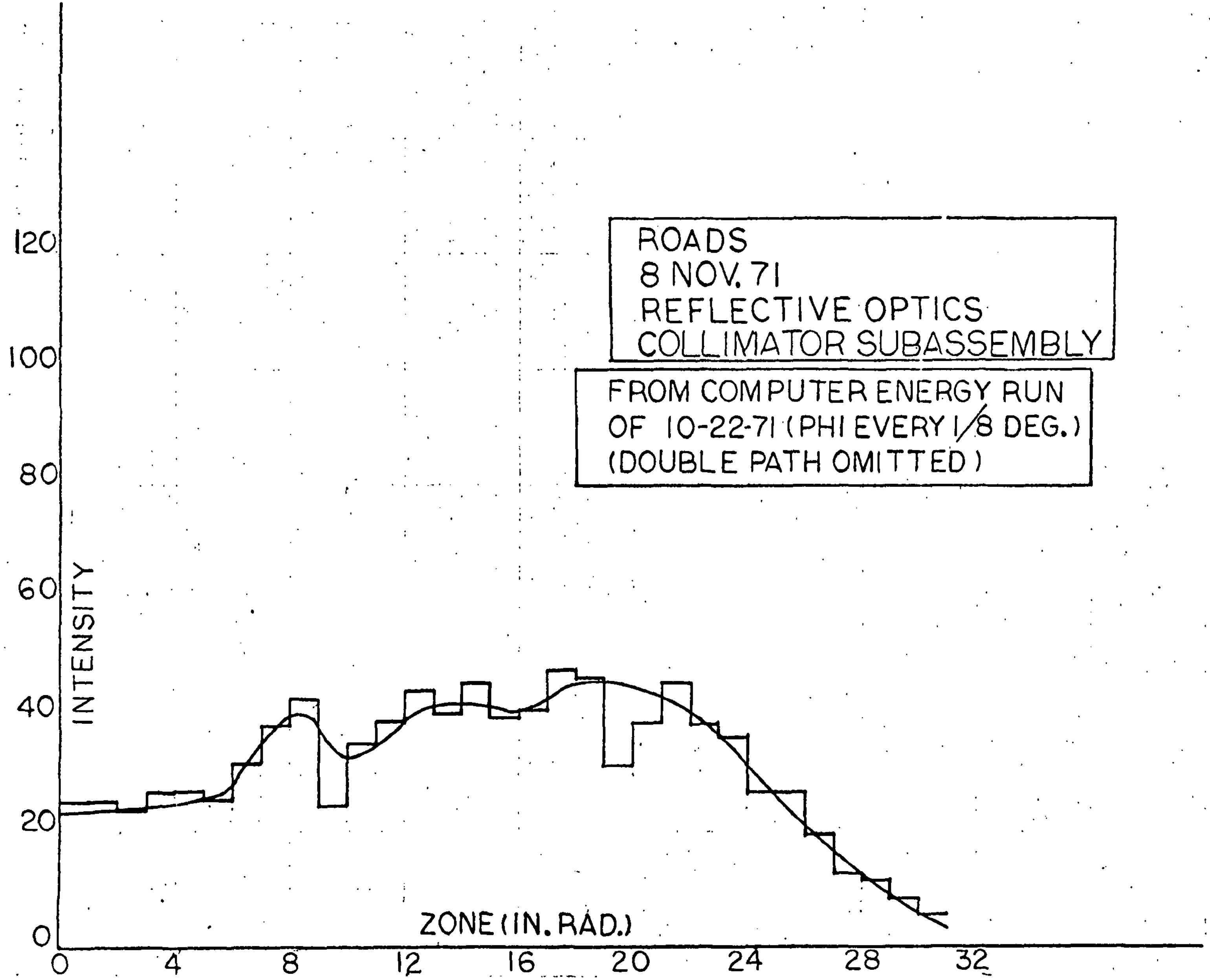


Figure 6-2. Distribution of Reflective Optics Collimator Subassembly

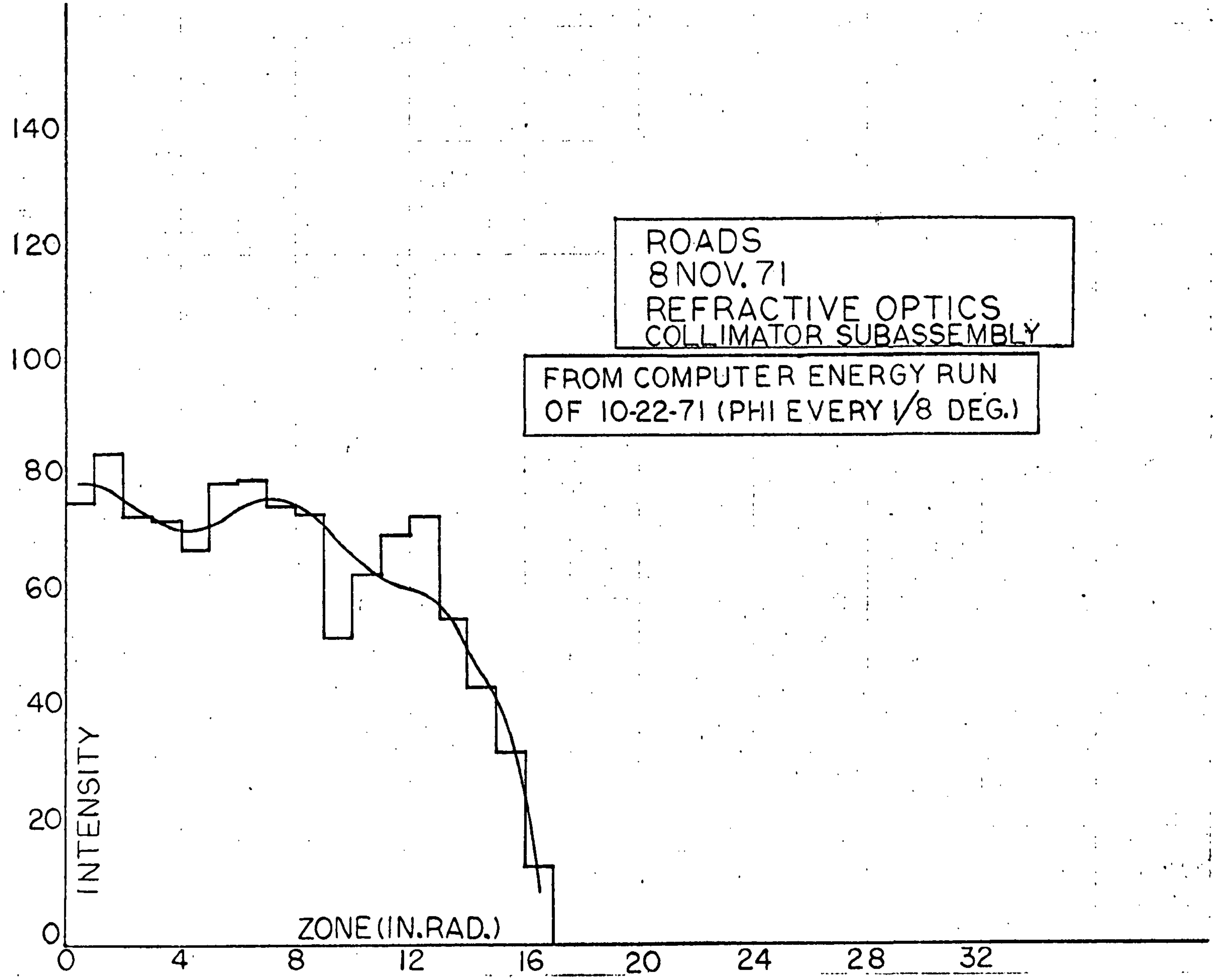


Figure 6-3. Distribution of Refractive Optics Collimator Subassembly

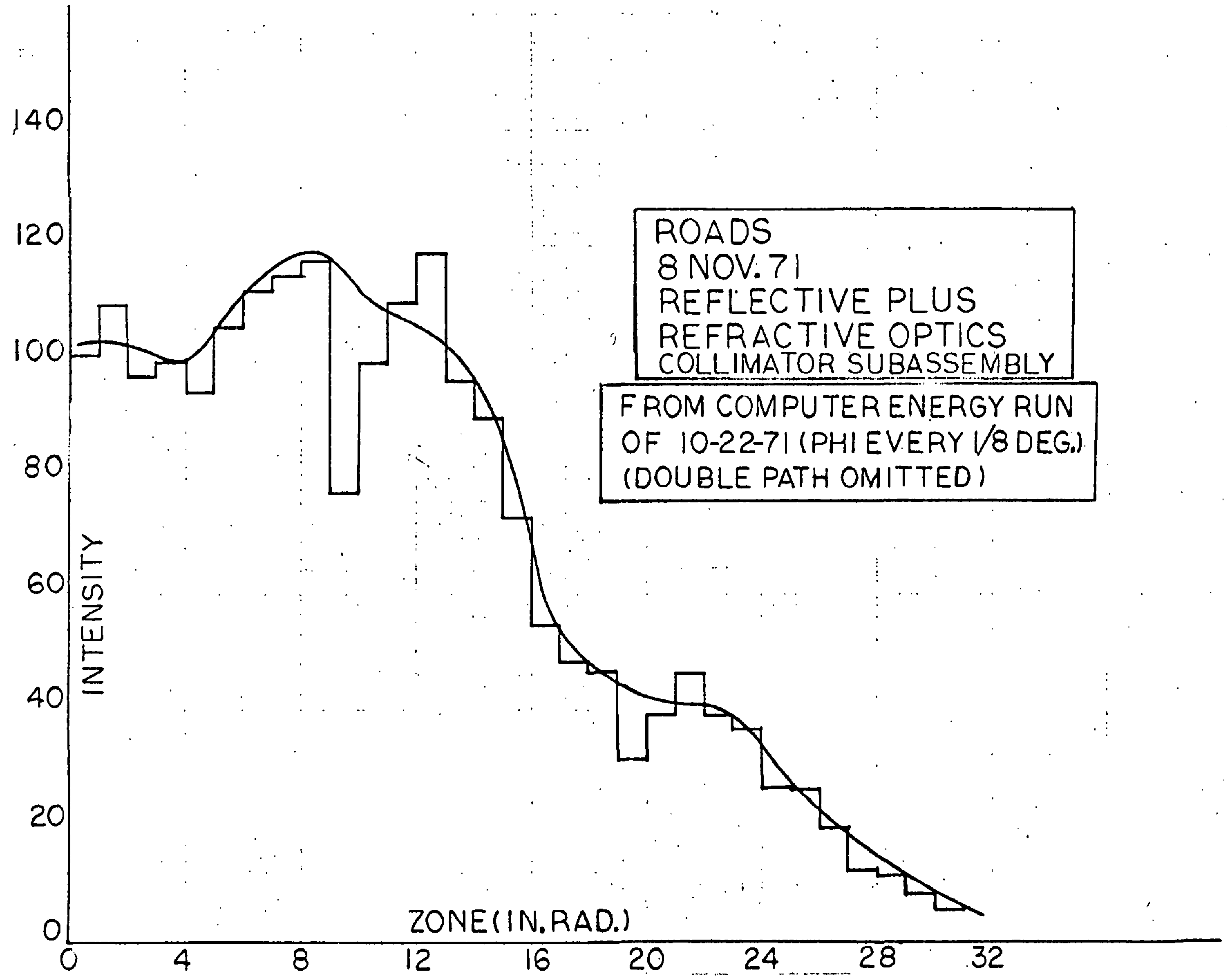


Figure 6-4. Distribution of Reflective Plus Refractive Optics Collimator Subassembly

Considering the nonuniformity at the plane of the field lens, the center of this plane sees as high as approximately 40 solar constants. Since this is much higher than the upper limit of the radiometer range, a neutral density filter, such as a perforated metal sheet (air cooled), could be used. Reducing the current of the C/A burner might be considered as a method of reducing the irradiance level. This method would not be good since both the size and the microradiance distribution would differ significantly from that of the full current arc. Since the test output will be compared to the nominal values generated by ENERGY and these nominals will be based on a mathematical model with a symmetrical source, and incandescent lamp is the better choice. Nominal tables have been developed by ENERGY and the same type of alignment procedures as described for the collimator (subsection 4.3) has been generated for this collector.

6.1.3.2 Xenon System

The only optical component is this system is the deep reflector recently developed for the conversion from carbon arc to 20 kW xenon. This deep reflector with the 20 kW xenon arc source is the complete collector system. Backward imaging will produce very accurate alignment. This can be verified by the use of a 500-watt halogen-quartz lamp with the filament in the same position as the xenon arc.

A realistic efficiency (electrical input to radiant energy through the field lens) expected from this type of reflector with a xenon lamp is approximately 0.25 which is the result of

$$\eta_{conv} \times \eta_{intercept} \times \eta_{refl} \times \eta_{spill} = 0.50 \times 0.80 \times 0.85 \times 0.75$$
$$= 0.25 \text{ efficiency}$$

when

η_{conv} = electrical conversion to total radiant output

$\eta_{intercept}$ = percent of radiant output intercepted by the collector

η_{refl} = reflectance coefficient of the vapor deposited aluminum through the overall spectrum

η_{spill} = spill over as expressed by ratio of energy through the field lens to the total energy reaching the plane of the field lens

The beam produced can then be scanned. The ultimate system that could be implemented for the sensor is the use of a "dummy" lamp. This lamp would have the mechanical mounting points of a 20 kW lamp.

6.1.4 MODULE TESTING

Aligned subassemblies will be mounted on the full module test bench and scanned for module performance. Either a carbon arc burner or a xenon compact arc lamp will be the source in its collector as used in the chamber.

6.2 MULTIMODULAR TESTING

6.2.1 MULTIMODULAR PREDICTION

The procedure for predicting multimodular performance is simple and straightforward. The data for the three modules is called for from the master data file by Task 10 producing a CRT display at the intersection of the three modules. There are two intersections which are typical of all the intersections, i.e., two on top with one on the bottom and one

on the top and two on the bottom (see figure B-36 and figure B-37). It is possible to input the data for one module in two or all three positions for analytical purposes. See subsections 5.4.1, 5.4.3, and 5.4.4.

Multimodular testing will be possible only in the chamber since there is no test bench capable of accommodating three modules. For this test the center point of the scanner is positioned at a point corresponding to the intersection in question.

6.3 SYSTEM OUTPUT USAGE

6.3.1 CATALOG OF COMPONENT, SUBASSEMBLY, AND MODULE PERFORMANCE

Most of the catalog will consist of line printer output. In addition, isointensity chart output of the plotter will be stored in the catalog (see Section 5). The punched card output consisting of ID and FOM values, although not physically part of the catalog, performs the same function (stored information for future reference) as the other catalog information.

6.3.2 PREDICTION OF MODULE PERFORMANCE

Module performance can be measured on the appropriate test bench in the alignment area. Any combination of collector-collimator can be predicated by the FOM algorithm described in subsections 5.4.3, 4.2.3, and 4.3.4.

APPENDIX A

ROADS FLOW CHARTS

ROADS OPERATIONAL COMMENTS
(Referred to in the figures)

NO.	
1	INCORRECT SETUP FOR SELECTED MODE . . . CHECK ALIGNMENT GUIDE (BLINK) RESET SCANNER, CORRECT SETUP, START SCANNER (NO BLINK)
2.	DATA COLLECTION COMPLETE. SEE CRT PGS 2-7 FOR REDUCED DATA
3.	DATA FOR UNIT ABCDEFGH ADDED TO MASTER DATA FILE
4.	DATA FOR UNIT ABCDEFGH CANNOT BE ADDED TO MASTER DATA FILE
5.	DATA WAS NOT GENERATED UNDER MODES 4, 7, OR 8
6.	MASTER DATA FILE CONTAINS DATA FOR THIS UNIT
7.	REQUESTED UNIT NOT FOUND IN MASTER DATA FILE
8.	DATA FOR UNIT ABCDEFGH STORED IN PERFORMANCE DATA BUFFER
9.	UNIT ABCDEFGH DELETED FROM MASTER DATA FILE
10.	MASTER DATA FILE CHANGED TO UNIT
11.	SUMMARY OF CONTENTS OF MASTER DATA FILE PRODUCED ON $\begin{pmatrix}\text{LINE PRINTER}\\\text{CARD PUNCH}\\\text{CRT}\end{pmatrix}$
12.	DATA FOR UNIT ABCDEFGH ADDED TO PLOT TAPE

UPLINK COMPUTER MAIN PROGRAM

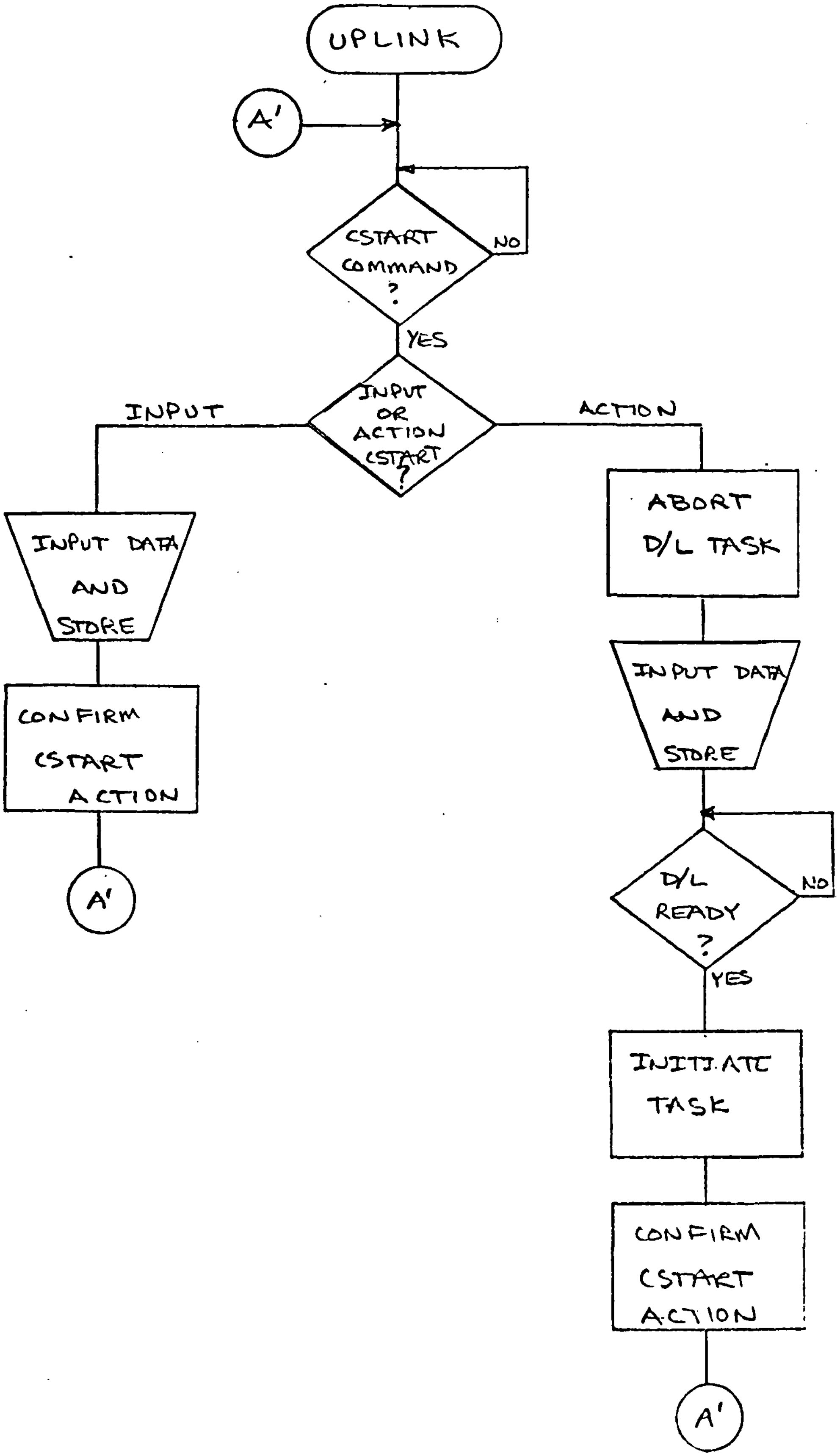


Figure A-1

DOWNLINK COMPUTER MAIN PROGRAM

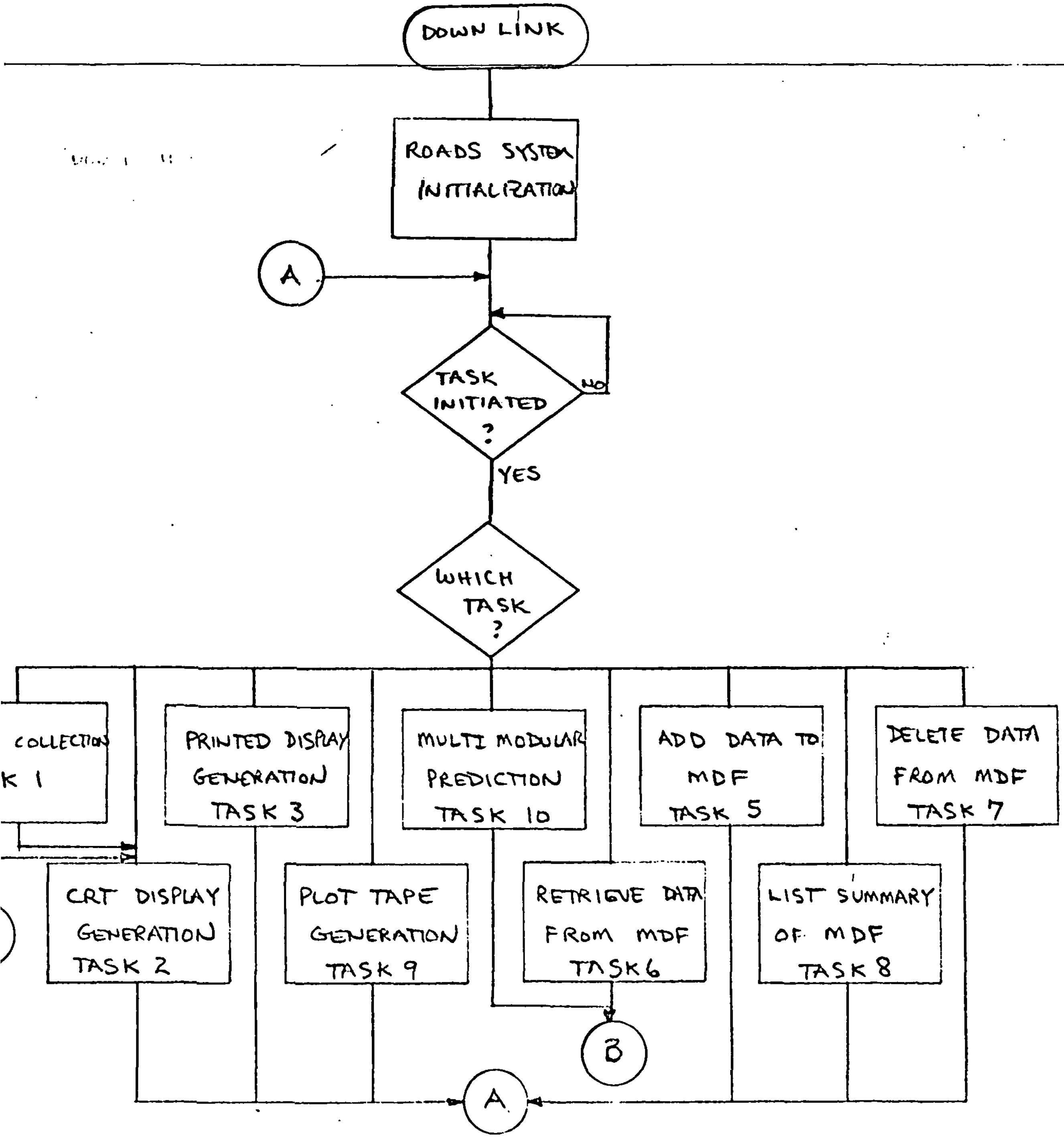


Figure A-2

DATA COLLECTION / REDUCTION (TASK 1)

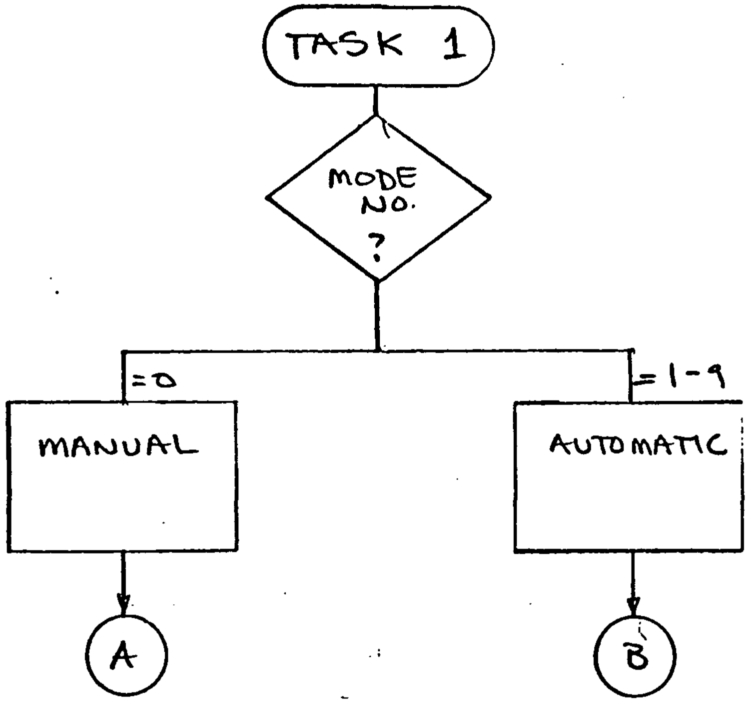


Figure A-3

DATA COLLECTION MODE 0 - MANUAL

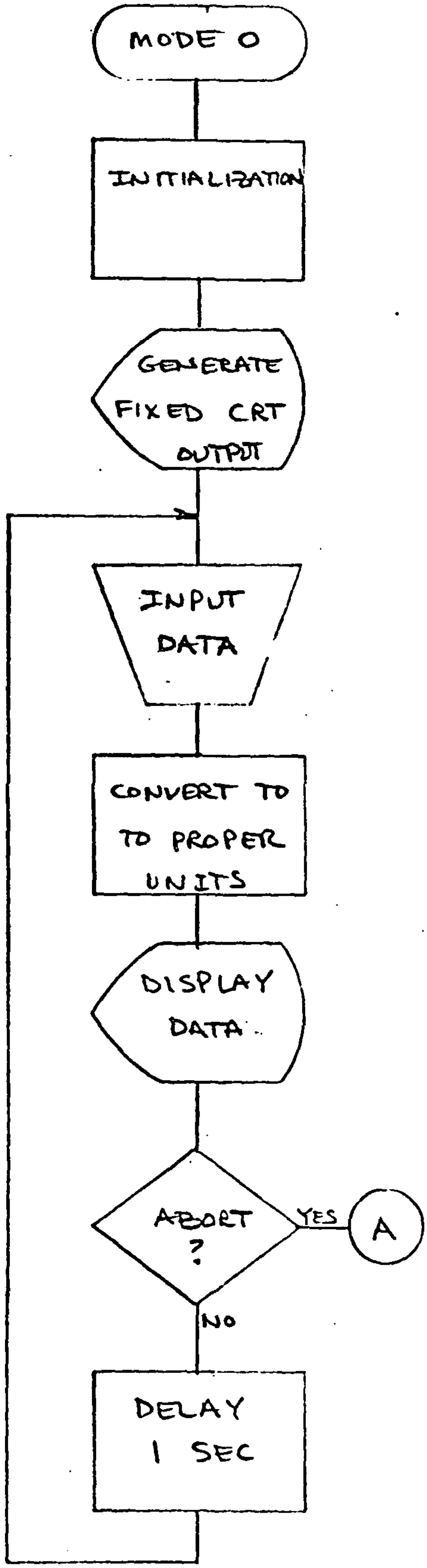


Figure A-4

DATA COLLECTION / REDUCTION MODES 1-9
(TASK 1)

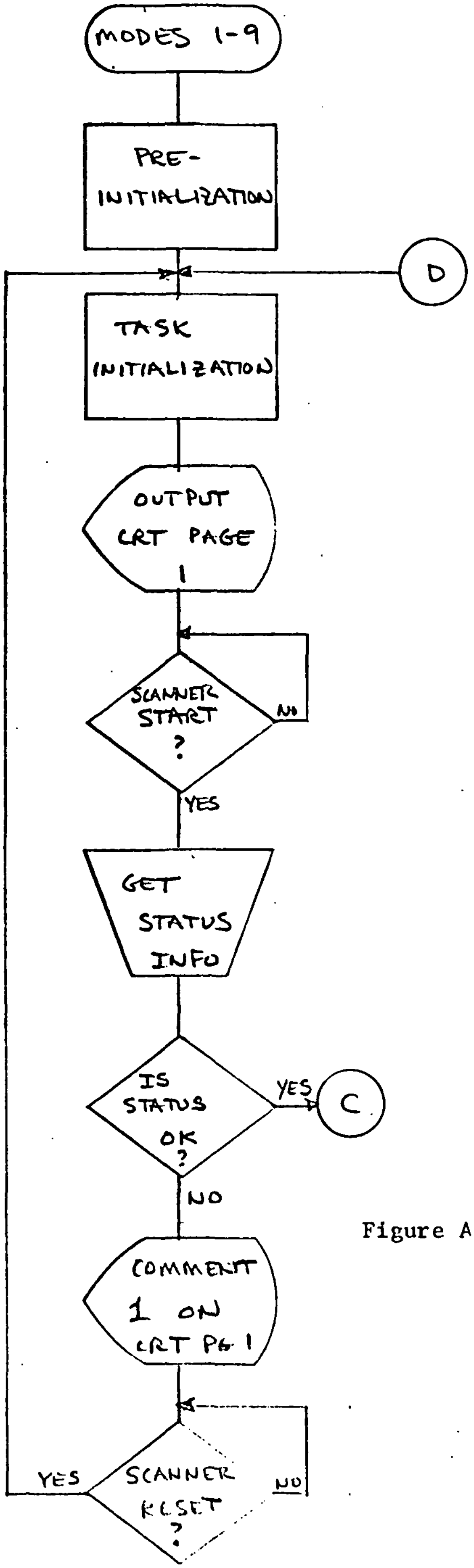


Figure A-5

DATA COLLECTION/REDUCTION MODES (1-9) (CONTINUED)

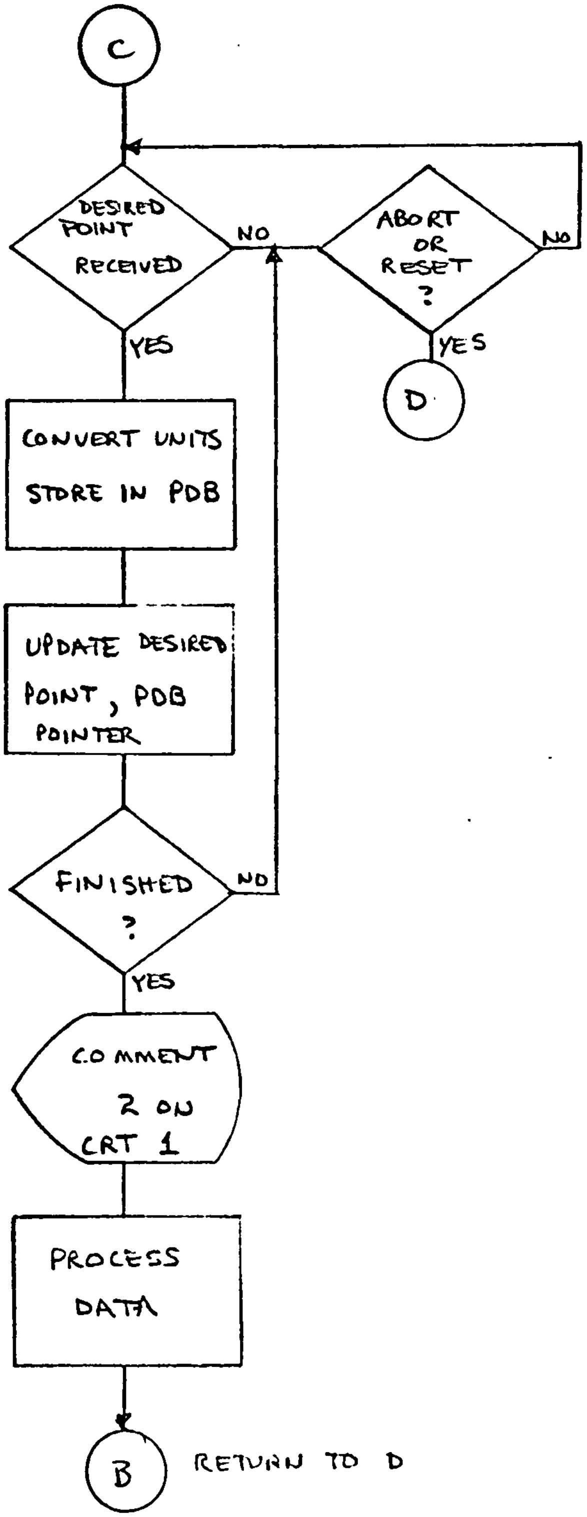


Figure A-6

GENERATION OF CRT DISPLAYS (TASK 2)

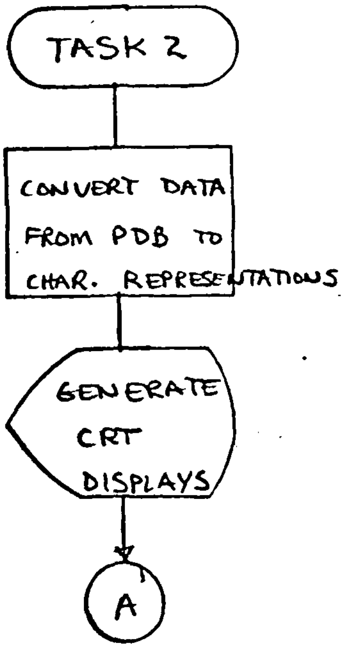


Figure A-7

LIST UNIT PERFORMANCE DATA ON LINE PRINTER (TASK 3)

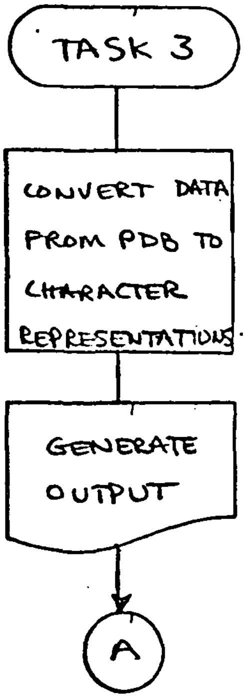


Figure A-8

INITIALIZATION OF MASTER DATA FILE (TASK4)

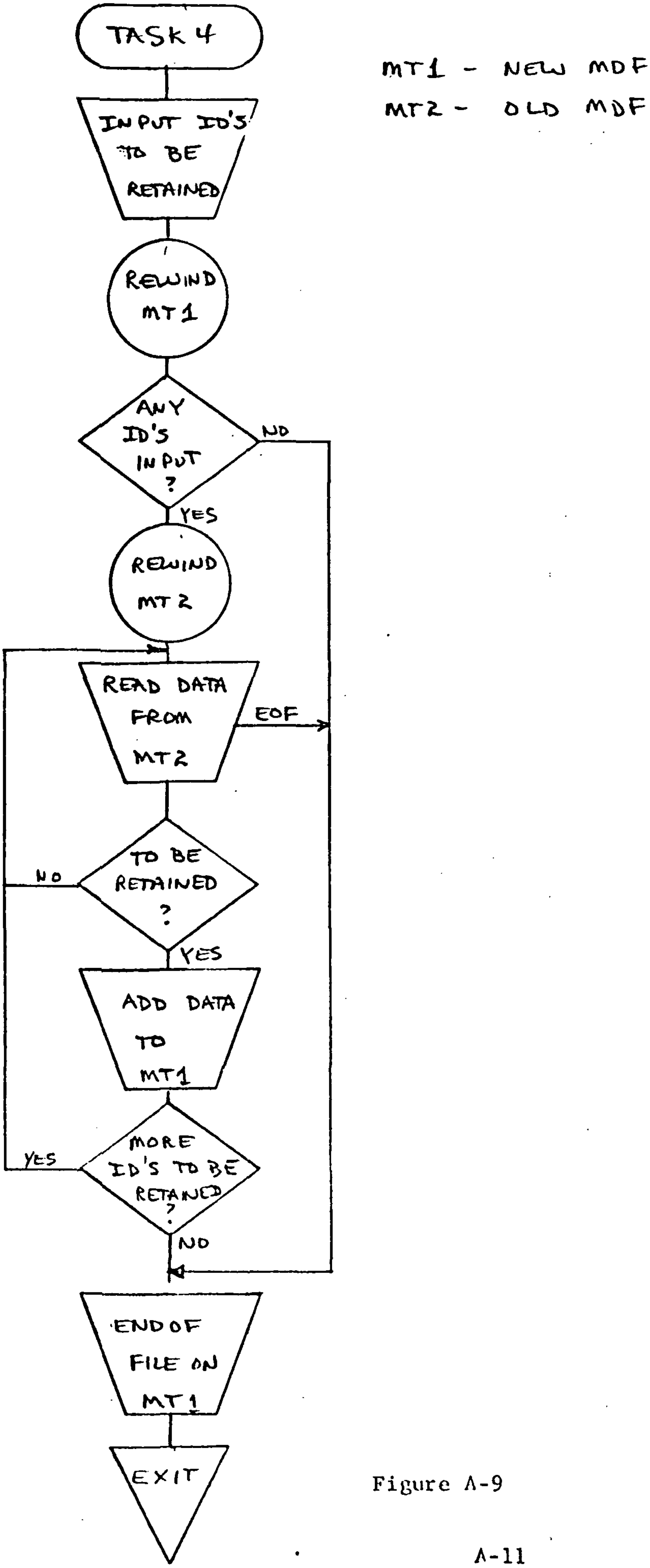
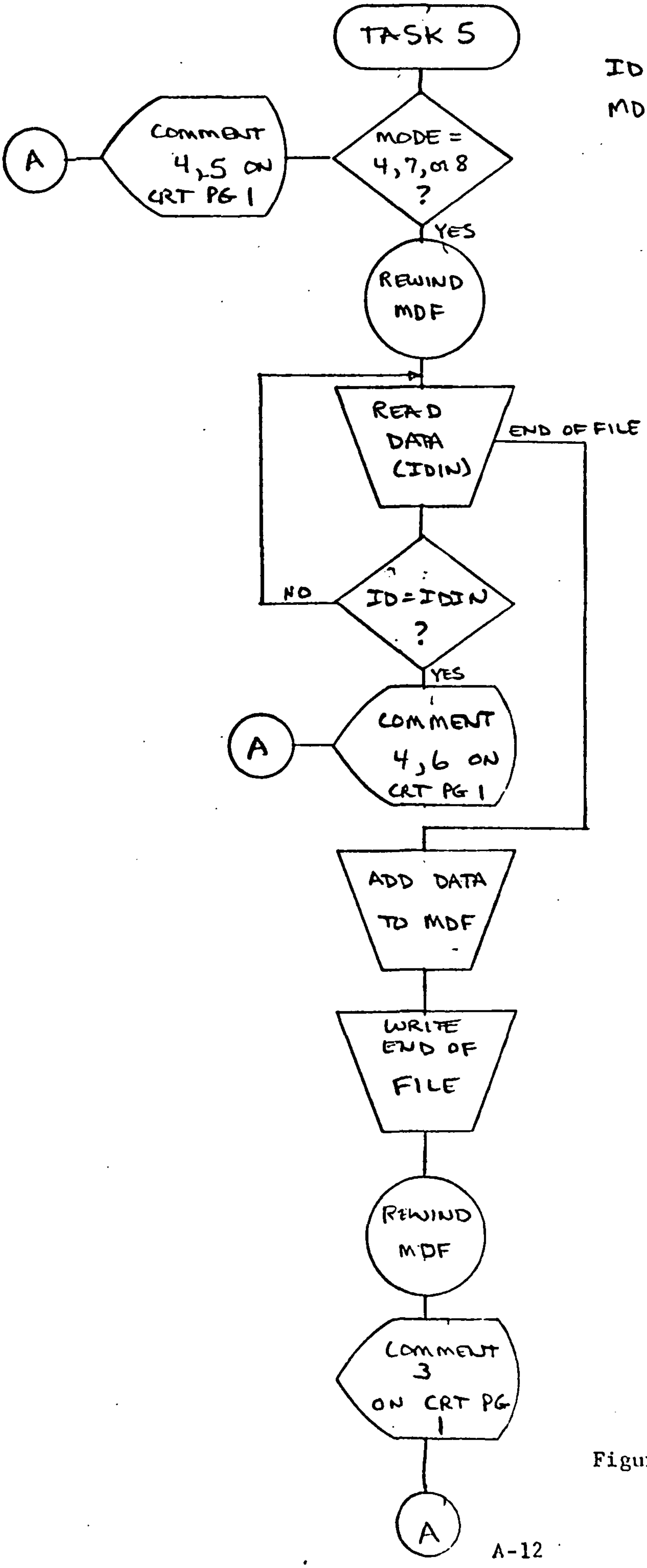


Figure A-9

ADD PERFORMANCE DATA TO MDF (TASK 5)



ID - ID for data to be added
MDF - magnetic tape containing Master Data File

Figure A-10

OBTAIN PERFORMANCE DATA FROM MASTER DATA FILE (TASK 6)

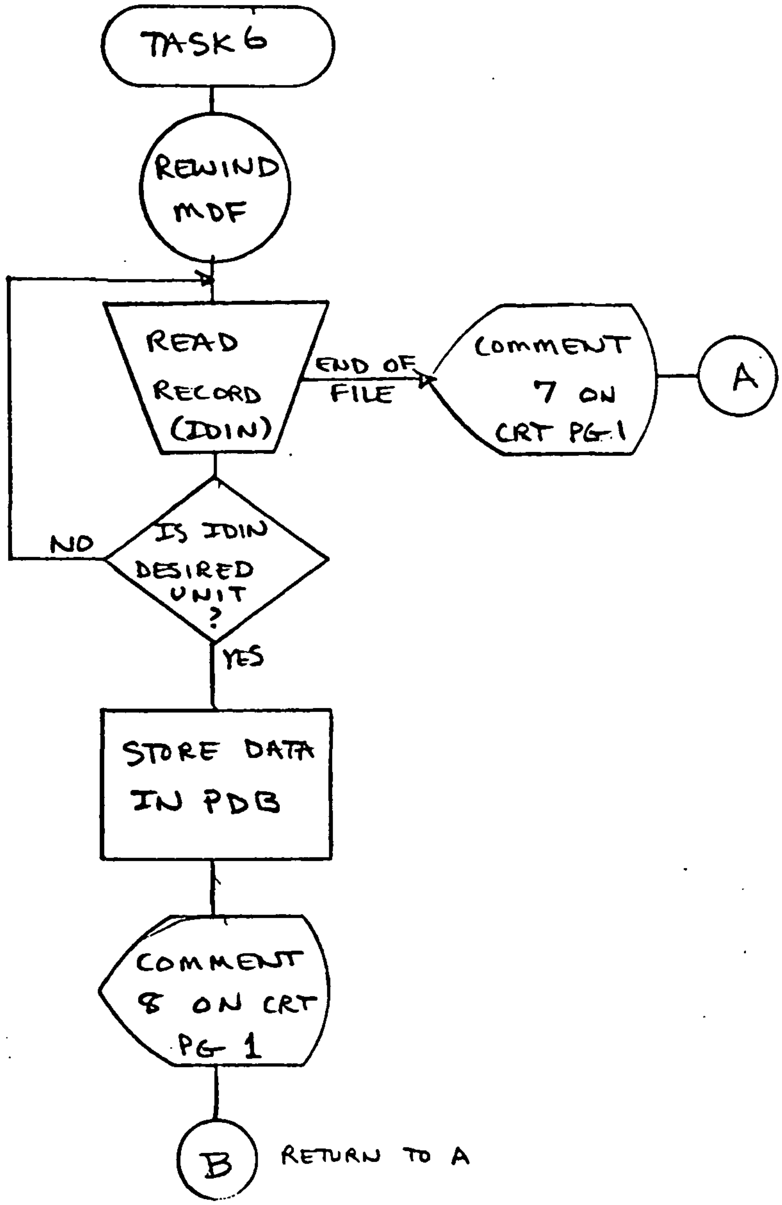
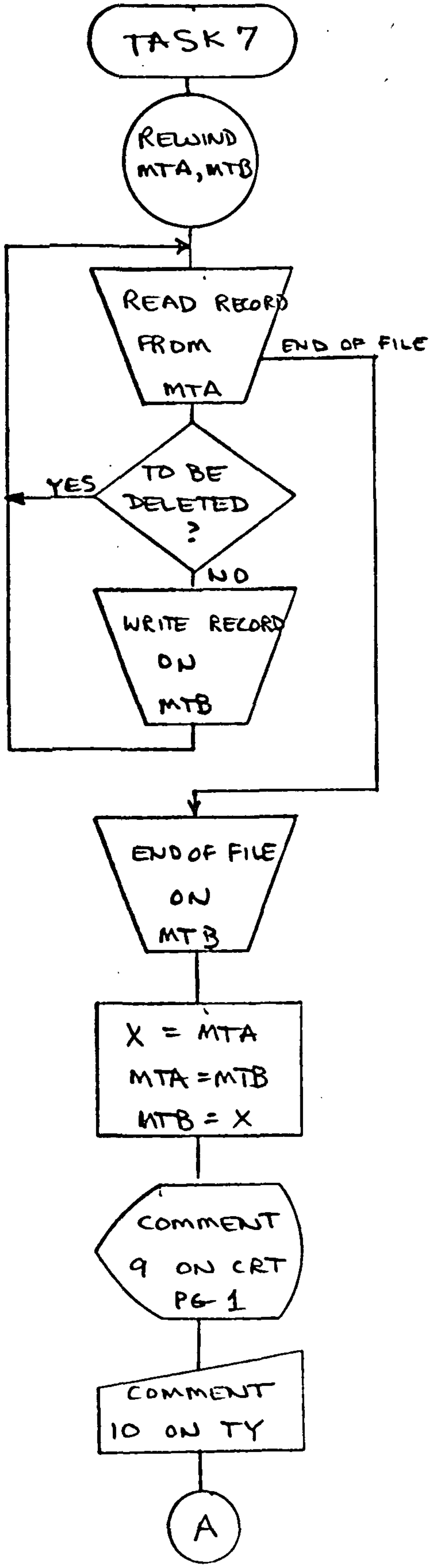


Figure A-11

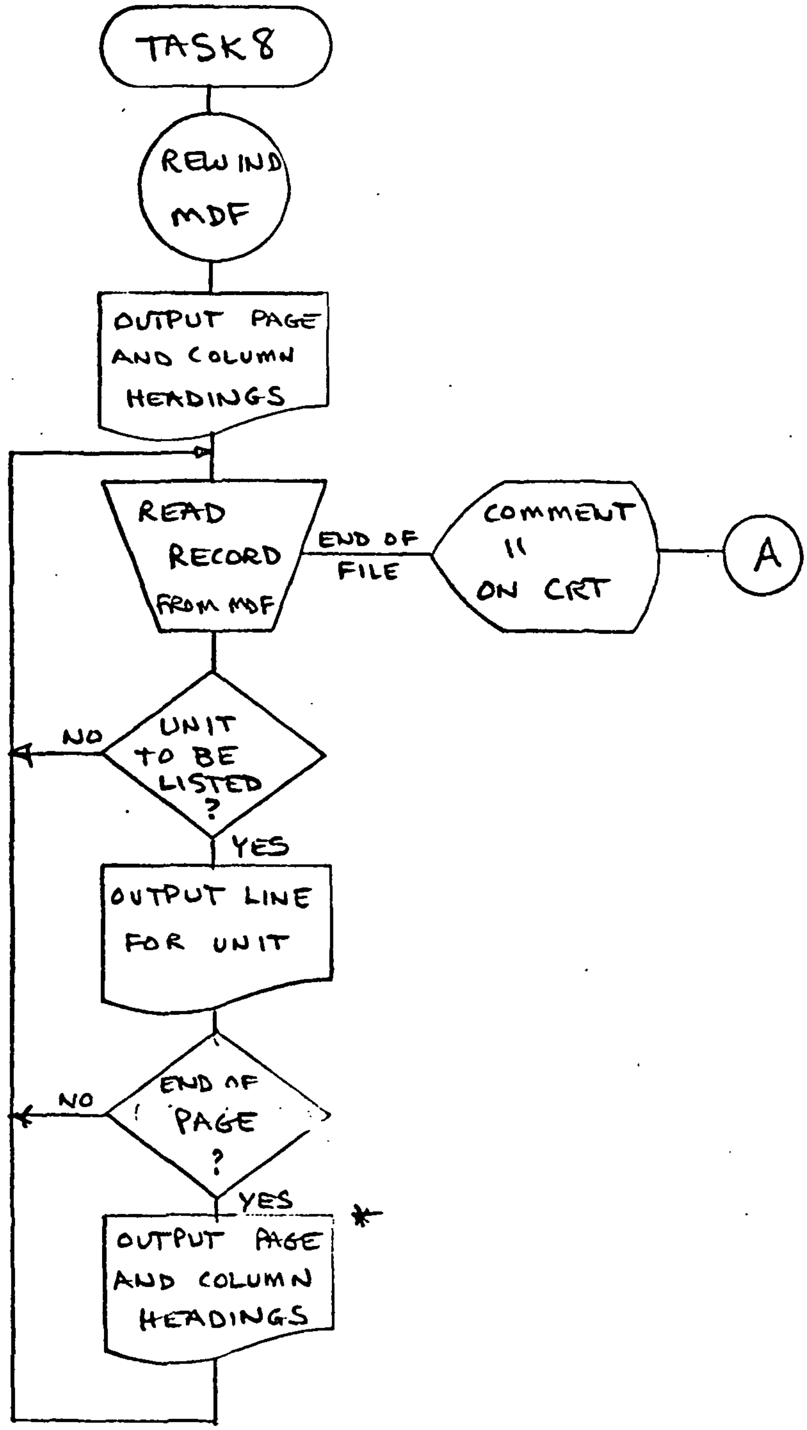
DELETE PERFORMANCE DATA FROM MASTER DATA FILE (TASK 7)



MTA - current MDF
MTB - new MDF

Figure A-12

LIST SUMMARY OF MASTER DATA FILE (TASK 8)



*) FOR LINE PRINTER AND CRT OUTPUT ONLY

Figure A-13

GENERATION OF PLOT TAPE (TASK 9)

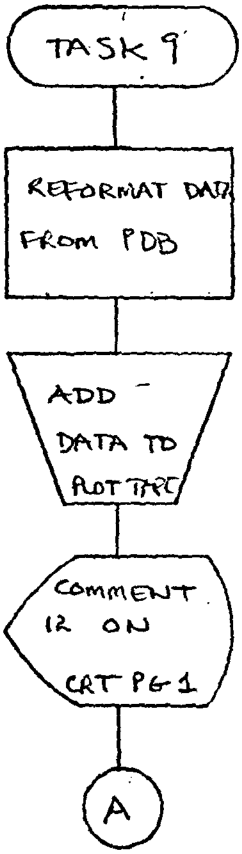
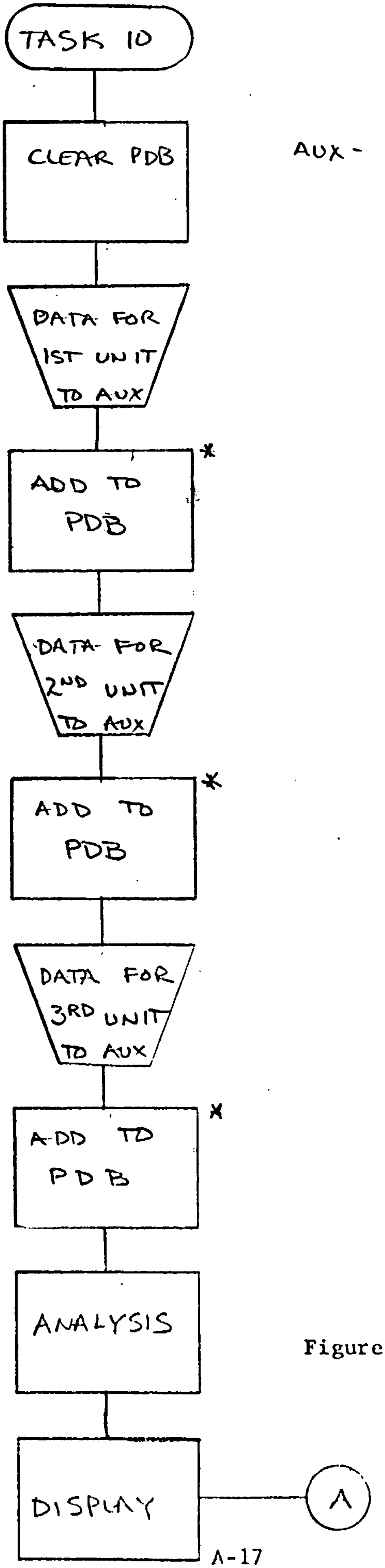


Figure A-14

MULTIMODULAR PREDICTION TASK (TASK 10)



AUX - auxillary data buffer

Figure A-15

* Only appropriate data from AUX is added to PDB

APPENDIX B

CRT OUTPUT EXAMPLES

```
ROADS MODE 0 - MANUAL CONTROL

UNIT - XXXXXXXX
MODE - MANUAL
DATE - XX/XX/XX

 MEASUREMENT      POSITION
 NO.   FLUX       X      Y
       (SC)     (IN)   (IN)

 1     X.XX    ±XX.X  ±XX.X
 2     X.XX    ±XX.X  ±XX.X
 3     X.XX    ±XX.X  ±XX.X
 4     X.XX    ±XX.X  ±XX.X
```

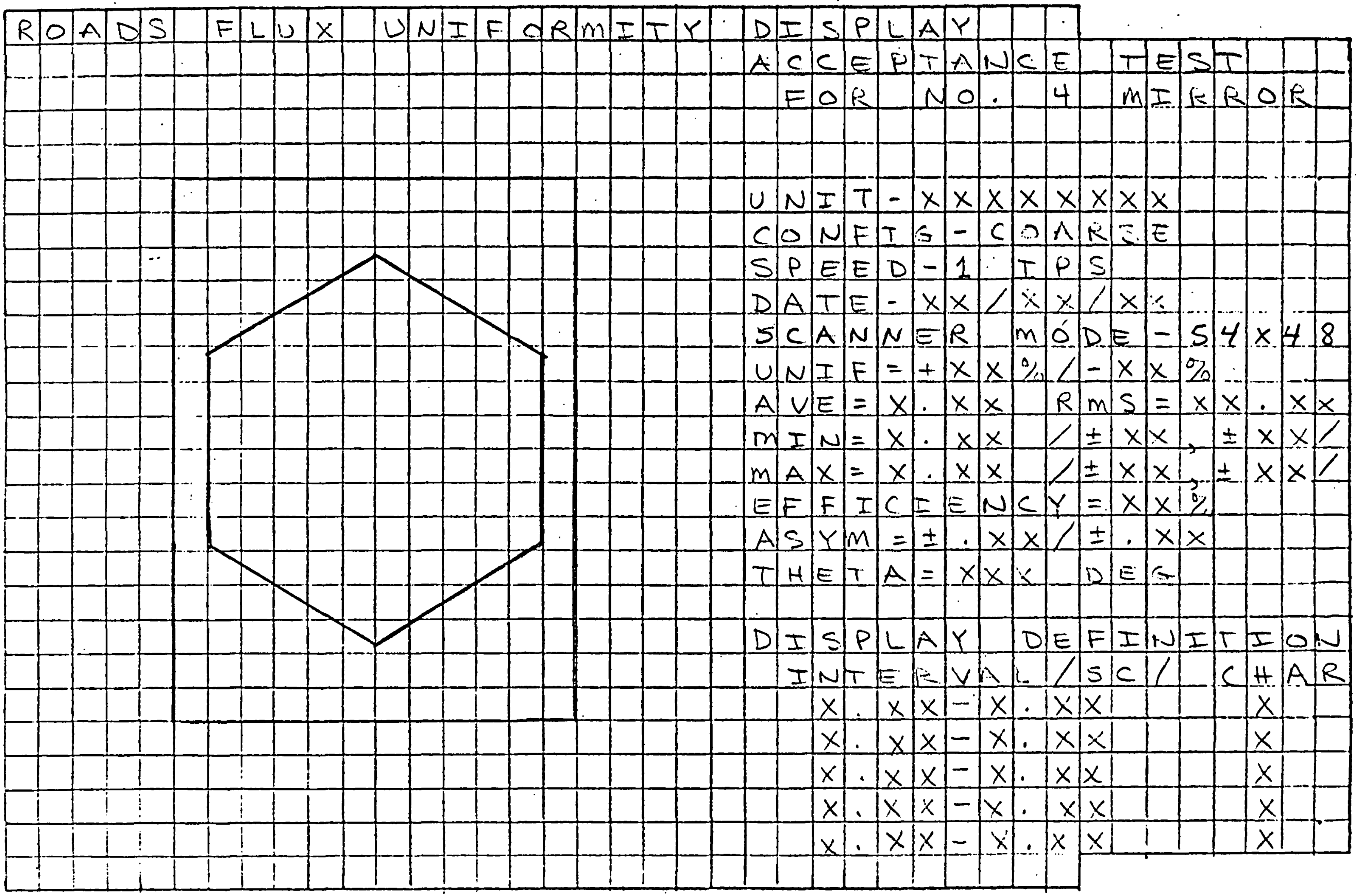
Figure B-1

Task 1 mode 0 page

```
  ROADS MODE 1 - ACCEPTANCE TEST
   NO 4 PARABOLOID HEX MIRROR
                         DATE-XX/XX/XX

SETUP...
  SOURCE- XENON LAMP /5MIN WARMUP/
  SCANNER MODE- 54X48
  SCANNER CONFIG-COAKSE WITH LENS

ROADS CONTROL...
  CSTARTS-00ABCDEFGH  /MIRROR ID/
          0300000000  /PRINTER LISTING/

ROADS SCANNER CONTROL...
  PRESS START BUTTON TO BEGIN SCAN.
   TO ABORT SCAN...PRESS RESET BUTTON
```

Figure B-2

Task 1, mode 1, pg 1



Task 1, mode 1, pg 2

Figure B-3

```
ROADS MODE 2 - ALIGNMENT TEST
    C/A COLLECTOR - REFLECTIVE OPTICS


SETUP...
    SOURCE- MINIATURE INCANDESCENT LAMP
    SCANNER MODE- 12X12
    SCANNER CONFIG-FINE
    DOUSER FOR NO 1 LENS IN PLACE
ROADS INITIALIZATION...
    CSTARTS-00ABCDEFGH   /COLLECTOR ID/
            0300000000   /PRINTER LISTING/

ROADS SCANNER CONTROL...
    PRESS START BUTTON TO BEGIN SCAN
     TO ABORT SCAN...PRESS RESET BUTTON

ALIGNMENT PHASES
    1. TILT OR OFF-AXIS TRANSLATION/ASYM/
    2. AXIAL TRANSLATION
```

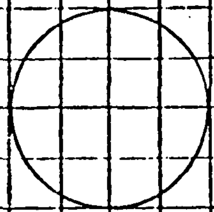
Figure B-4

Task 1, mode 2, pg 1

ROADS FLUX UNIFORMITY DISPLAY

ALIGNMENT OF C/A
COLLECTOR OPTICS
-REFLECTIVE ONLY-

UNIT-XXX:XXXX
CONFIG-FINE
SPEED- X IPS
DATE-XX/XX/XX
SCANNER MODE-12X12
AV=±X.XX RMS=XX.XX
MIN=X.XX /±XX, ±XX/
MAX=X.XX /±XX, ±XX/
EFFICIENCY=XX%
ASYM=±.XX/±.XX
THETA=XXX DEG



DISPLAY DEFINITION
INTERVAL/SC/ CHAR
±X.XX-±X.XX X
±X.XX-±X.XX X
±X.XX-±X.XX X
±X.XX-±X.XX X
±X.XX-±X.XX X

ASYM=POOR AXIAL=GOOD

P2

Task 1, mode 2, pg 2

Figure B-5

```
ROADS MODE 3 - ALIGNMENT OF
  C/A COLLECTOR - REFRACTIVE OPTICS


SETUP...
    SOURCE- MINATURE INCANDESCENT LAMP
    SCANNER MODE- 12X12
    SCANNER CONFIG- FINE
    DOUSER FOR NO 2 MIRROR IN PLACE

ROADS INITIALIZATION...
    CSTARTS-00ABCDEFGH    /COLLECTOR ID/
            03 00000000   /PRINTER LISTING/

ROADS SCANNER CONTROL...
    PRESS START BUTTON TO BEGIN SCAN
      TO ABORT SCAN...PRESS RESET BUTTON

ALIGNMENT PHASES
    1. TILT OR OFF-AXIS TRANSLATION/ASYM/
    2. AXIAL TRANSLATION
```

Task 1, mode 3, pg 1

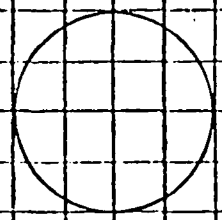
Figure B-6

ROADS FLUX UNIFORMITY DISPLAY

ALIGNMENT OF C/A
COLLECTOR OPTICS
-REFRACTIVE ONLY-

UNIT-XXXXXXXX
CONFIG-FINE
SPEED- X IPS
DATE-XX/XX/XX
SCANNER MODE-12X12
AV=±X.XX RMS=XX.XX
MIN=X.XX /±XX,±XX/
MAX=X.XX /±XX,±XX/
EFFICIENCY=XX%
ASYM=±.XX/±.XX
THETA=XXX DEG

DISPLAY DEFINITION
INTERVAL/SC/ CHAR
±X.XX-±X.XX X
±X.XX-±X.XX X
±X.XX-±X.XX X
±X.XX-±X.XX X
±X.XX-±X.XX X



ASYM=POOR AXIAL=GOOD

P2

Task 1, mode 3, pg 2

Figure B-7

```
ROADS MODE 4 - ALIGNMENT OF
        COLLECTOR - FULL OPTICS


SETUP...
  SOURCE- MINATURE INCANDESCENT LAMP
  SCANNER MODE- 12X12
  SCANNER CONFIG- FINE
  NO DOUSERS USED

ROADS INITIALIZATION...
  CSTARTS-00ABCDEFGH  /COLLECTOR ID/
          1400000005  /SOURCE/
          0300000000  /PRINTER LISTING/
          0500000000  /DATA TO MDF/
ROADS SCANNER CONTROL...
  PRESS START BUTTON TO BEGIN SCAN
   TO ABORT SCAN... PRESS RESET BUTTON

ALIGNMENT PHASES
  1. TILT OR OFF-AXIS TRANSLATION/ASYM/
  2. AXIAL TRANSLATION
```

Task 1, mode 4, pg 1

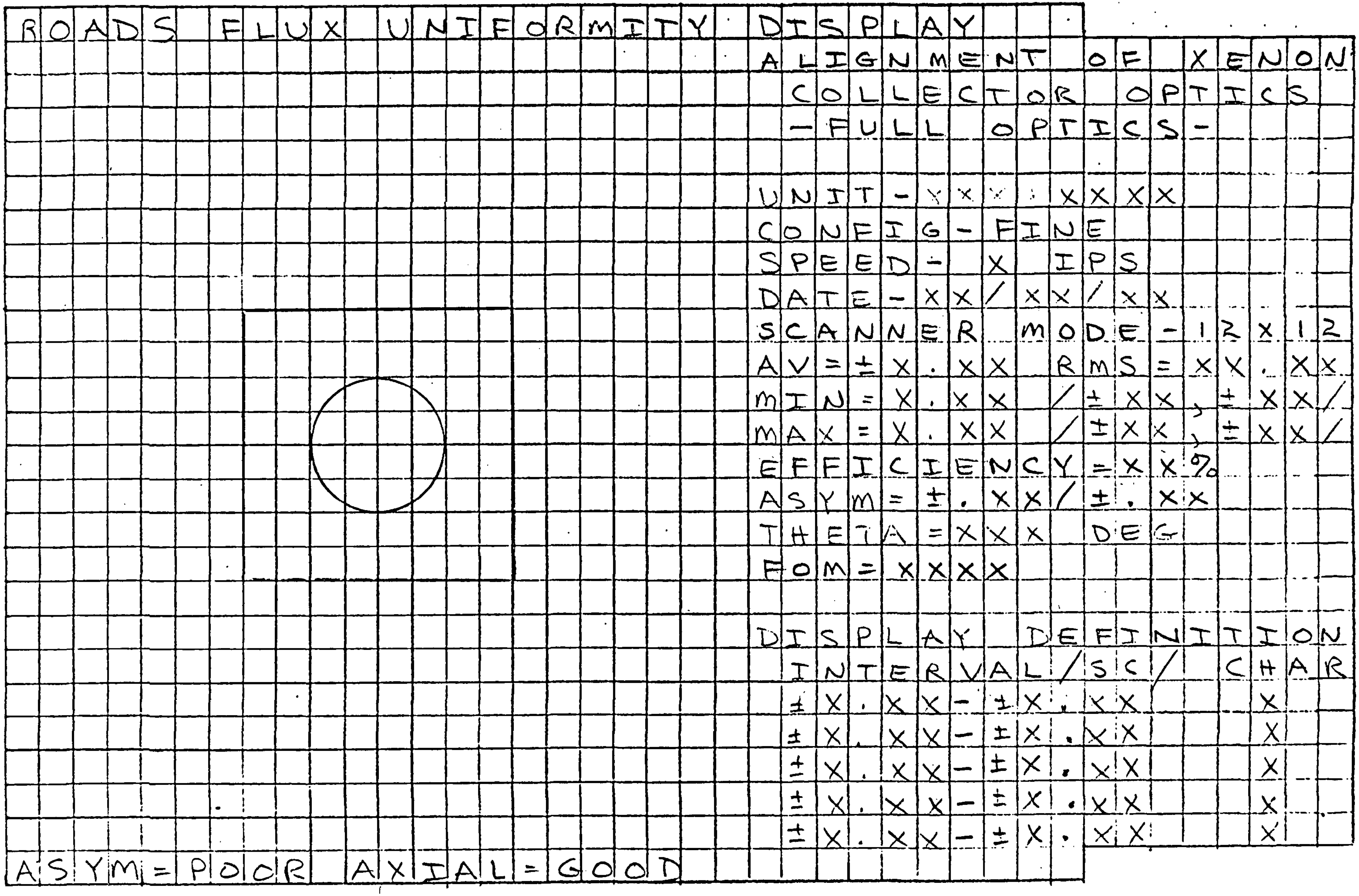
Figure B-8

```
ROADS FLUX UNIFORMITY DISPLAY
                              ALIGNMENT OF C/A
                               COLLECTOR OPTICS
                               -FULL OPTICS-

                              UNIT-XXXXXXXX
                              CONFIG-FINE
                              SPEED- X IPS
                              DATE-XX/XX/XX
                              SCANNER MODE-12X12
                              AV=±X.XX RMS=XX.XX
                              MIN=X.XX/±XX,±XX/
                              MAX=X.XX/±XX,±XX/
                              EFFICIENCY=XX%
                              ASYM=±.XX/±.XX
                              THETA=XXX DEG
                              FOM=XXXX

                              DISPLAY DEFINITION
                               INTERVAL/SC/ CHAR
                               ±X.XX-±X.XX   X
                               ±X.XX-±X.XX   X
                               ±X.XX-±X.XX   X
                               ±X.XX-±X.XX   X
                               ±X.XX-±X.XX   X
ASYM=POOR AXIAL=GOOD
```

p2

Task 1, mode 4, pg 2 C/A

Figur4 B-9



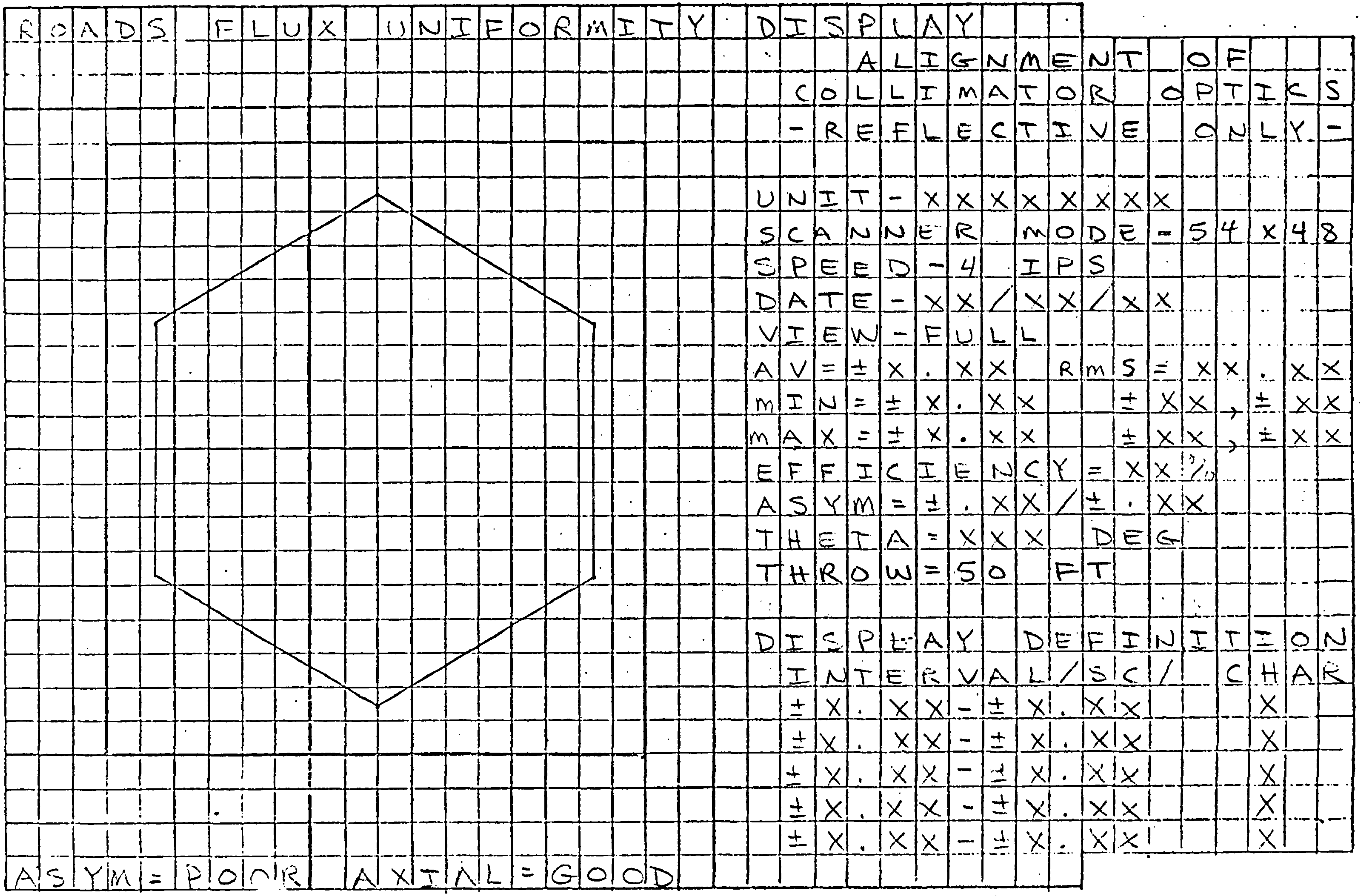
Task 1, mode 4, pg 2 Xenon

Fibure B-10

```
ROADS MODE 5 - ALIGNMENT OF
  COLLIMATOR - REFLECTIVE OPTICS
                           DATE-XX/XX/XX

SETUP...
  SOURCE-SIMULATED BURNER/COLLECTOR
  SCANNER MODE-54X48 OR 70X64
  SCANNER CONFIG-FINE
  DOUSER FOR NO 3 LENS IN PLACE

ROADS CONTROL...
  CSTARTS-00ABCDEFGH   /SUBASSEMBLY ID/
          1400000OTS   /THROW-SOURCE/
          0300000000   /PRINTER LISTING/
ROADS SCANNER CONTROL...
  PRESS START BUTTON TO BEGIN SCAN
   TO ABORT SCAN...PRESS RESET BUTTON

ALIGNMENT PHASES
  1. TILT OR OFF-AXIS TRANSLATION/ASYM/
  2. AXIAL TRANSLATION
```

Task 1, mode 5, pg 1

Figure B-11



Task 1, mode 5, pg 2

Figure B-12

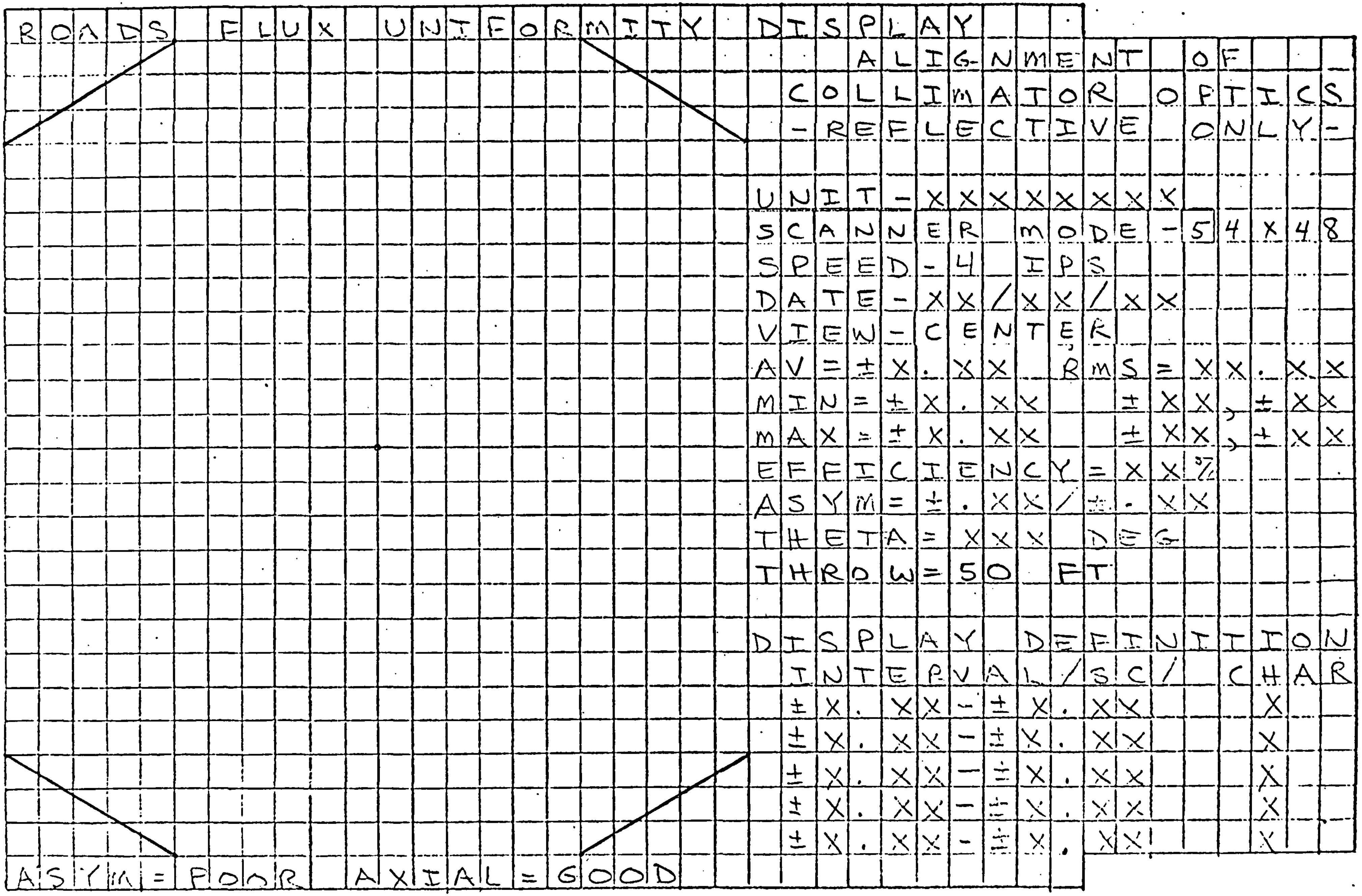


Figure B-13

Task1, mode 5, pg3

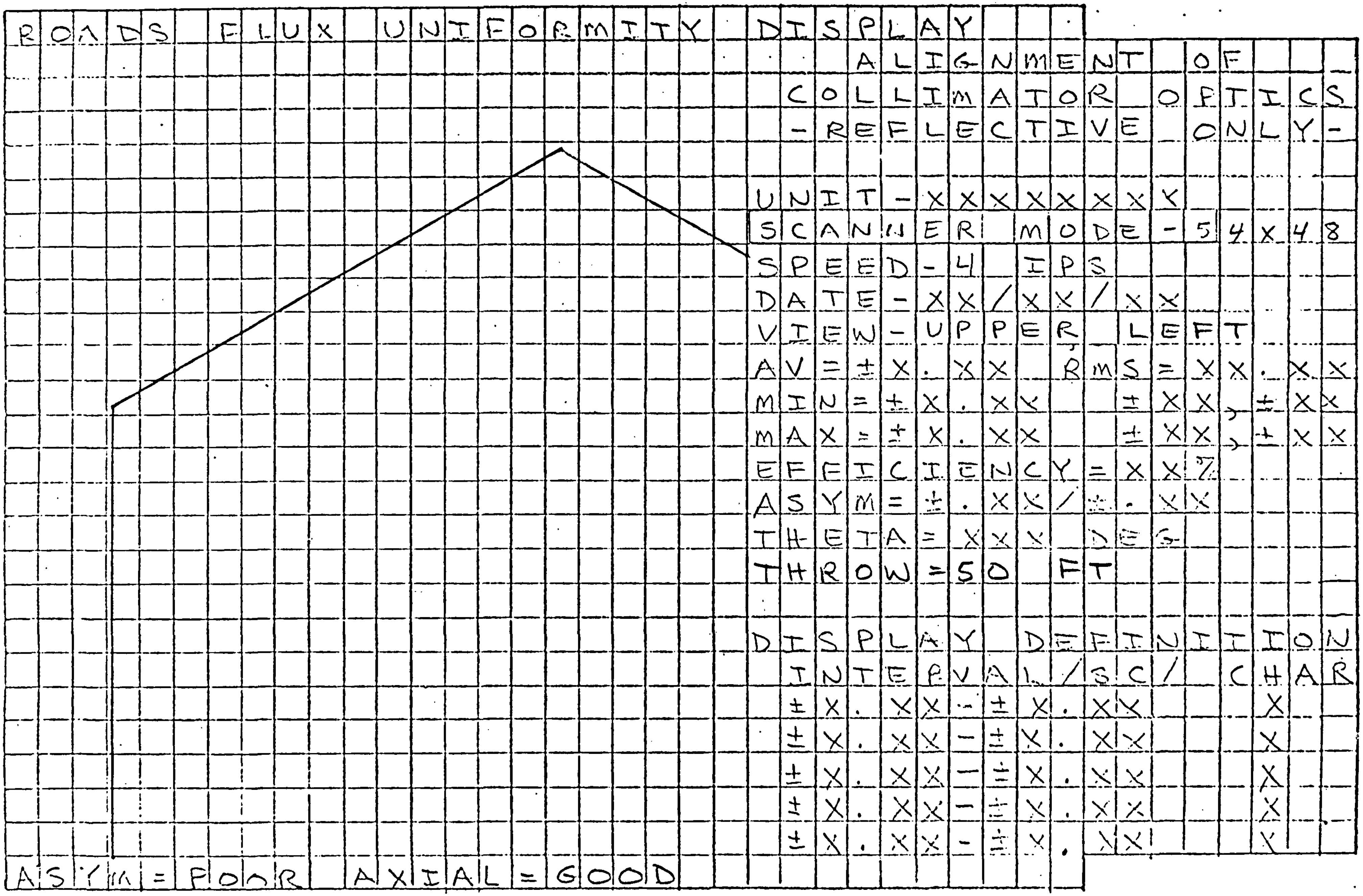
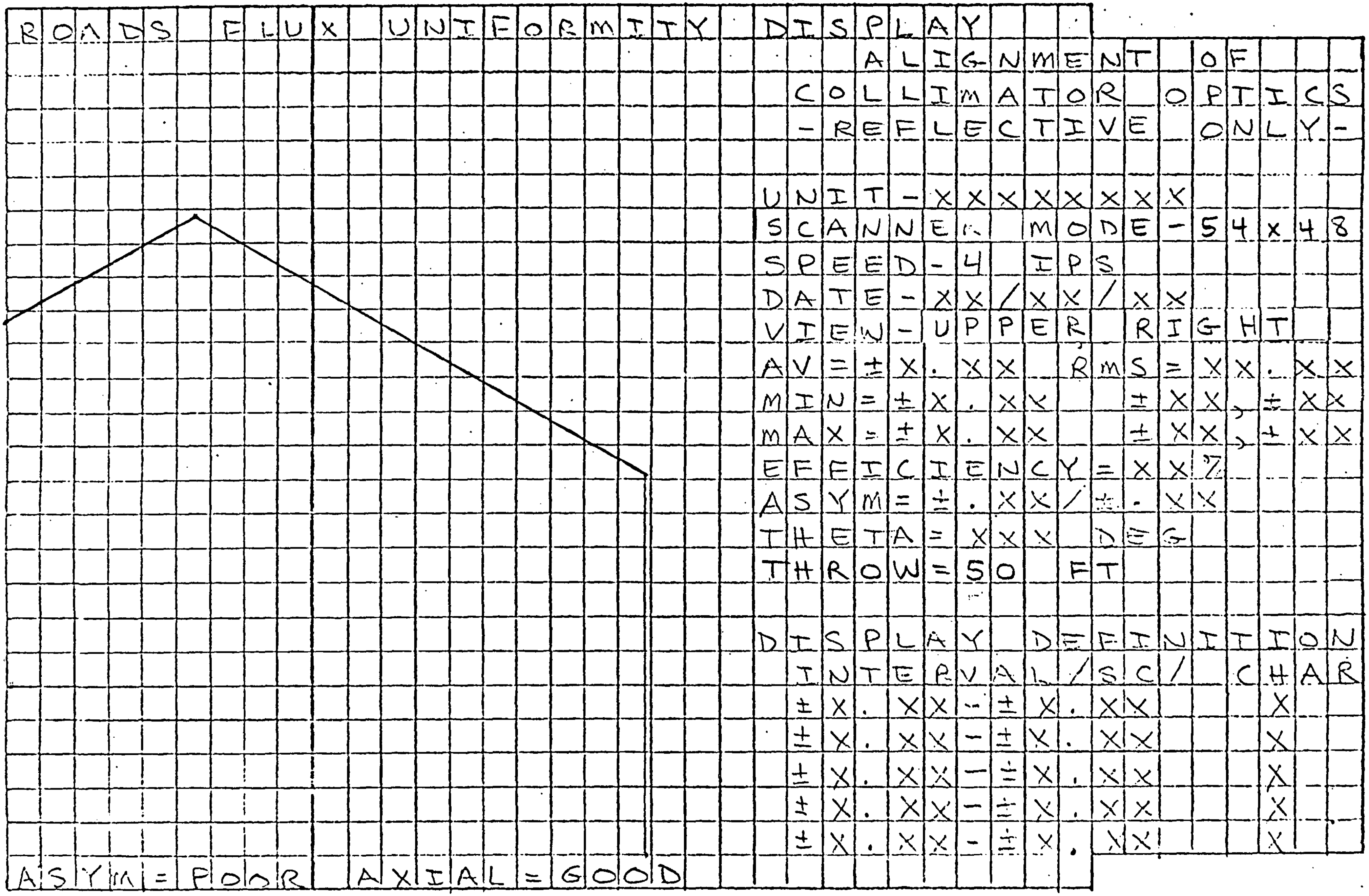


Figure B-14

Task 1, mode 5, pg 4



Task 1, mode 5, pg 5

Figure B-15

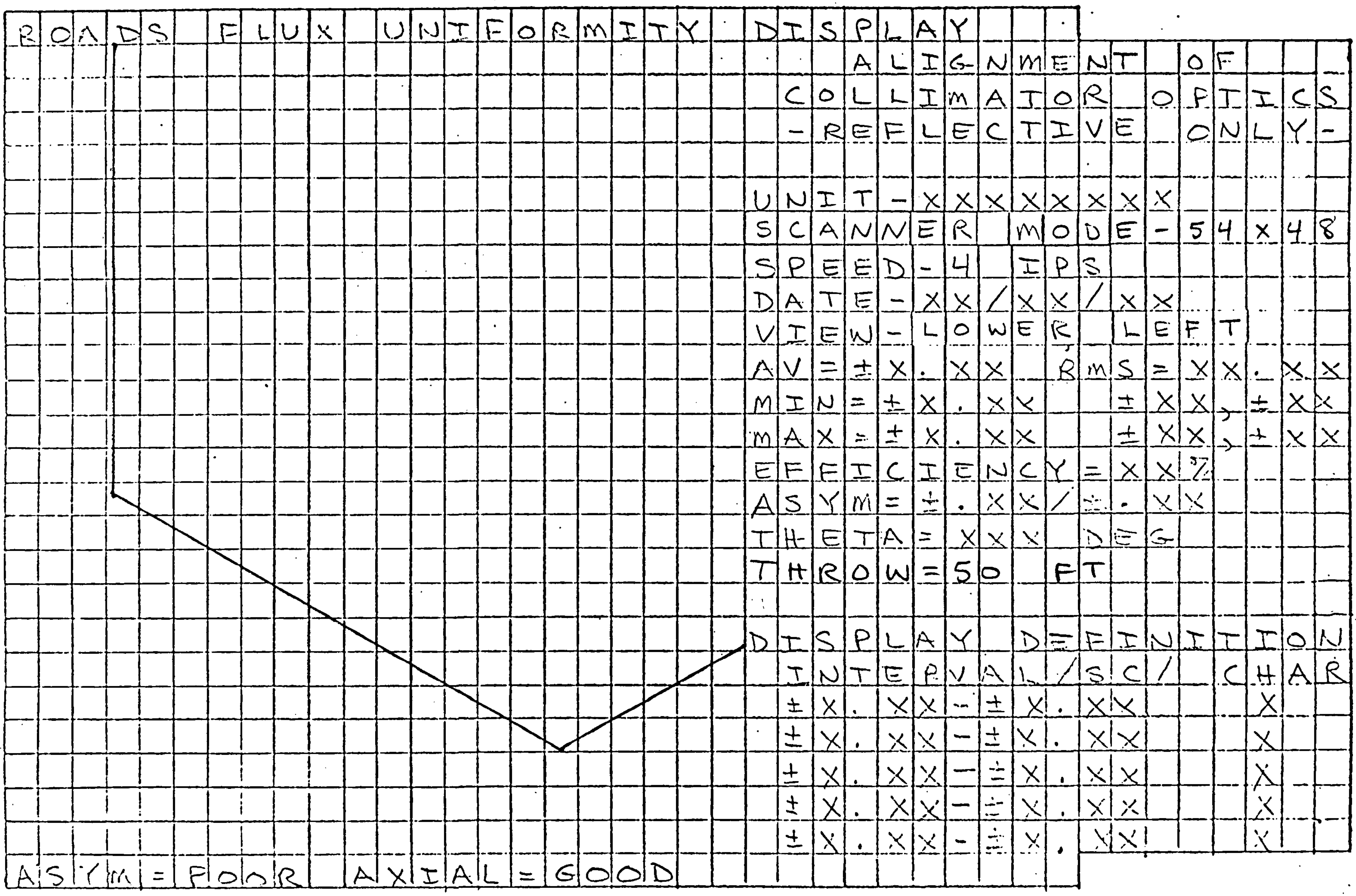


Figure B-16

Task 1, mode 5, pg 6

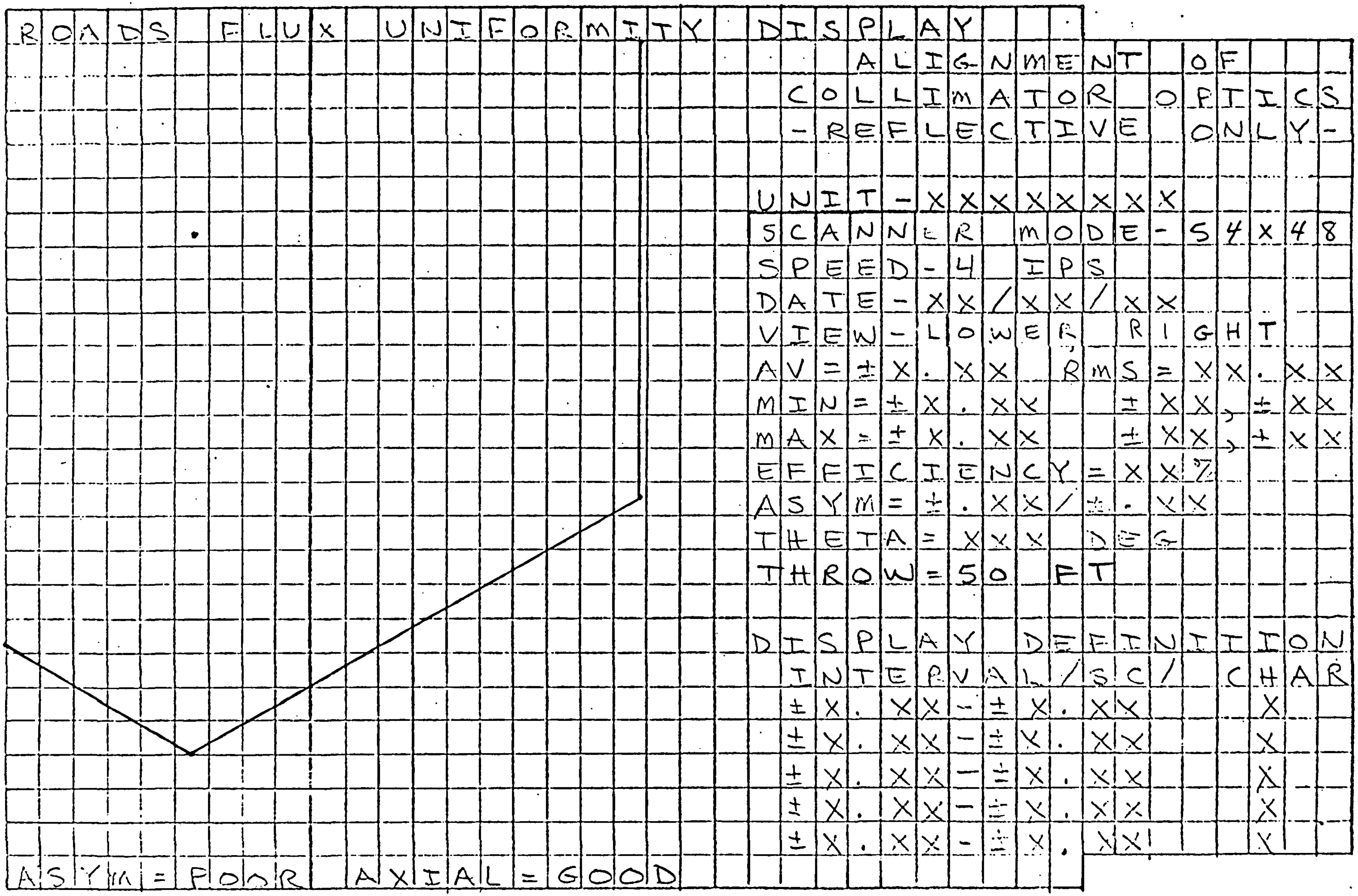


Figure B-17

Task 1, mode 5, pg 7

```
  ROADS MODE 6 - ALIGNMENT OF
   COLLIMATOR - REFRACTIVE OPTICS
                                DATE-XX/XX/XX

SETUP...
  SOURCE-SIMULATED BURNER/COLLECTOR
  SCANNER MODE- 30X30
  SCANNER CONFIG- FINE
  DOUSER FOR NO 3 MIRROR IN PLACE

ROADS CONTROL...
  CSTARTS-00ABCDEFGH  /COLLIMATOR ID/
          14000000TS  /THROW-SOURCE/
          0300000000  /PRINTER LISTING/

ROADS SCANNER CONTROL...
  PRESS START BUTTON TO BEGIN SCAN
   TO ABORT SCAN...PRESS RESET BUTTON

ALIGNMENT PHASES
  1. TILT OR OFF-AXIS TRANSLATION/ASYM/
  2. AXIAL TRANSLATION
```

Task 1, mode 6, pg 1

Figure B-18

```
ROADS FLUX UNIFORMITY DISPLAY
                          ALIGNMENT OF
                         COLLIMATOR OPTICS
                         -REFRACTIVE ONLY-

                        UNIT-XXXXXXXX
                        SCANNER MODE-30X30
                        SPEED-2 IPS
                        DATE-XX/XX/XX

                        AV=±X.XX  RMS=XX.XX
                        MIN=±X.XX  ±XX,±XX
                        MAX=±X.XX  ±XX,±XX
                        EFFICIENCY=XX%
                        ASYM=±.XX/±.XX
                        THETA=XXX DEG
                        THROW=65 FT

                        DISPLAY DEFINITION
                         INTERVAL/SC/  CHAR
                          ±X.XX-±X.XX   X
                          ±X.XX-±X.XX   X
                          ±X.XX-±X.XX   X
                          ±X.XX-±X.XX   X
                          ±X.XX-±X.XX   X
ASYM=POOR AXIAL=GOOD
```

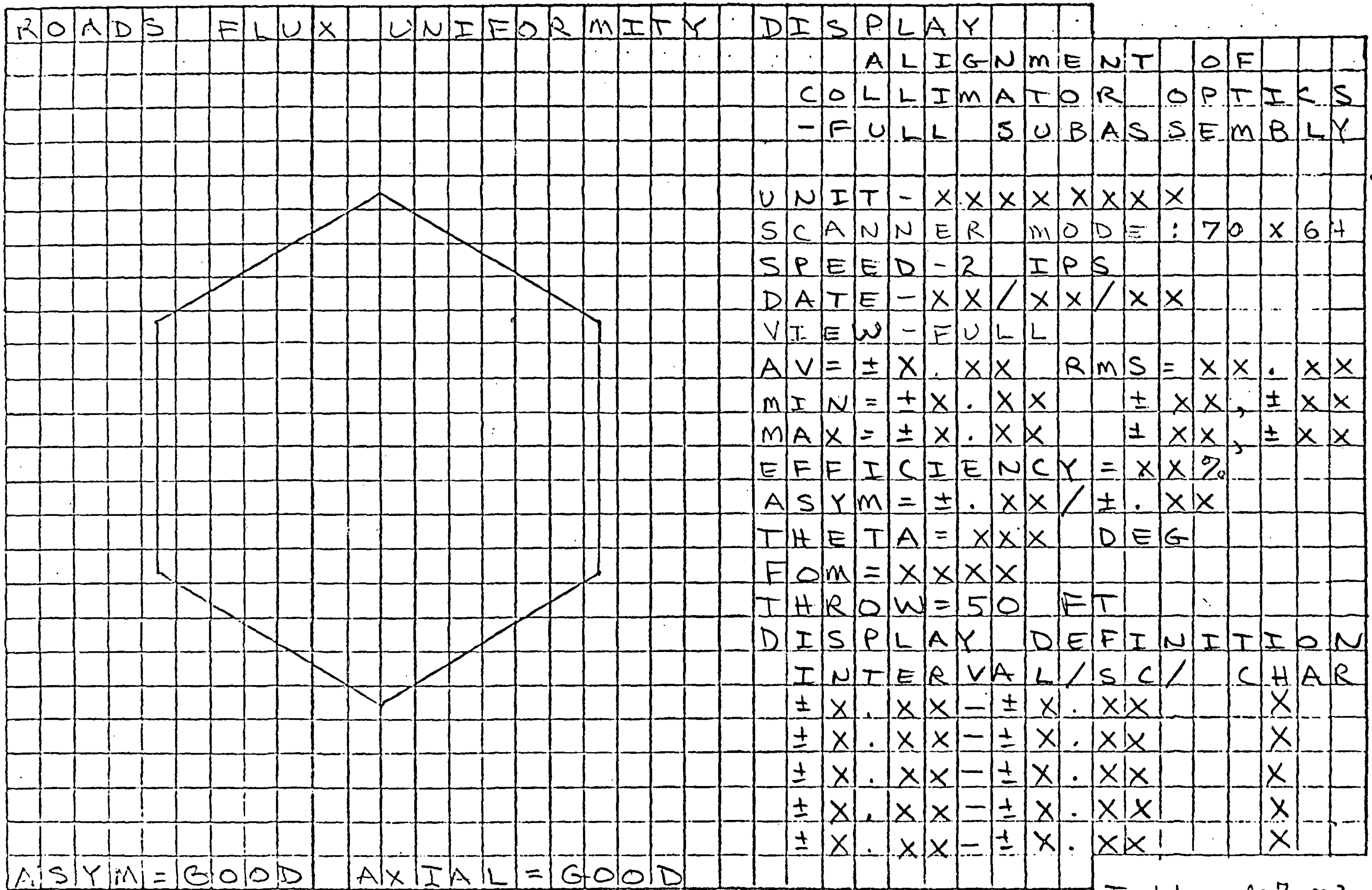
Task 1, mode 6 pg 2

Figure B-19

```
  ROADS MODE 7 - ALIGNMENT OF
   COLLIMATOR - FULL OPTICS
                           DATE - XX/XX/XX

SETUP...
  SOURCE-SIMULATED BURNER/COLLECTOR
  SCANNER MODE- 54X48 OR 70X64
  SCANNER CONFIG- FINE
  NO DOUSERS USED

ROADS CONTROL...
  CSTARTS-00ABCDEFGH   /COLLIMATOR ID/
          14000000TS   /THROW-SOURCE/
          0300000000   /PRINTER LISTING/
          0500000000   /DATA TO MDF/
ROADS SCANNER CONTROL...
  PRESS START BUTTON TO BEGIN SCAN
   TO ABORT SCAN...PRESS RESET BUTTON

ALIGNMENT PHASES
  1. TILT OR OFF-AXIS TRANSLATION/ASYM/
  2. AXIAL TRANSLATION
```

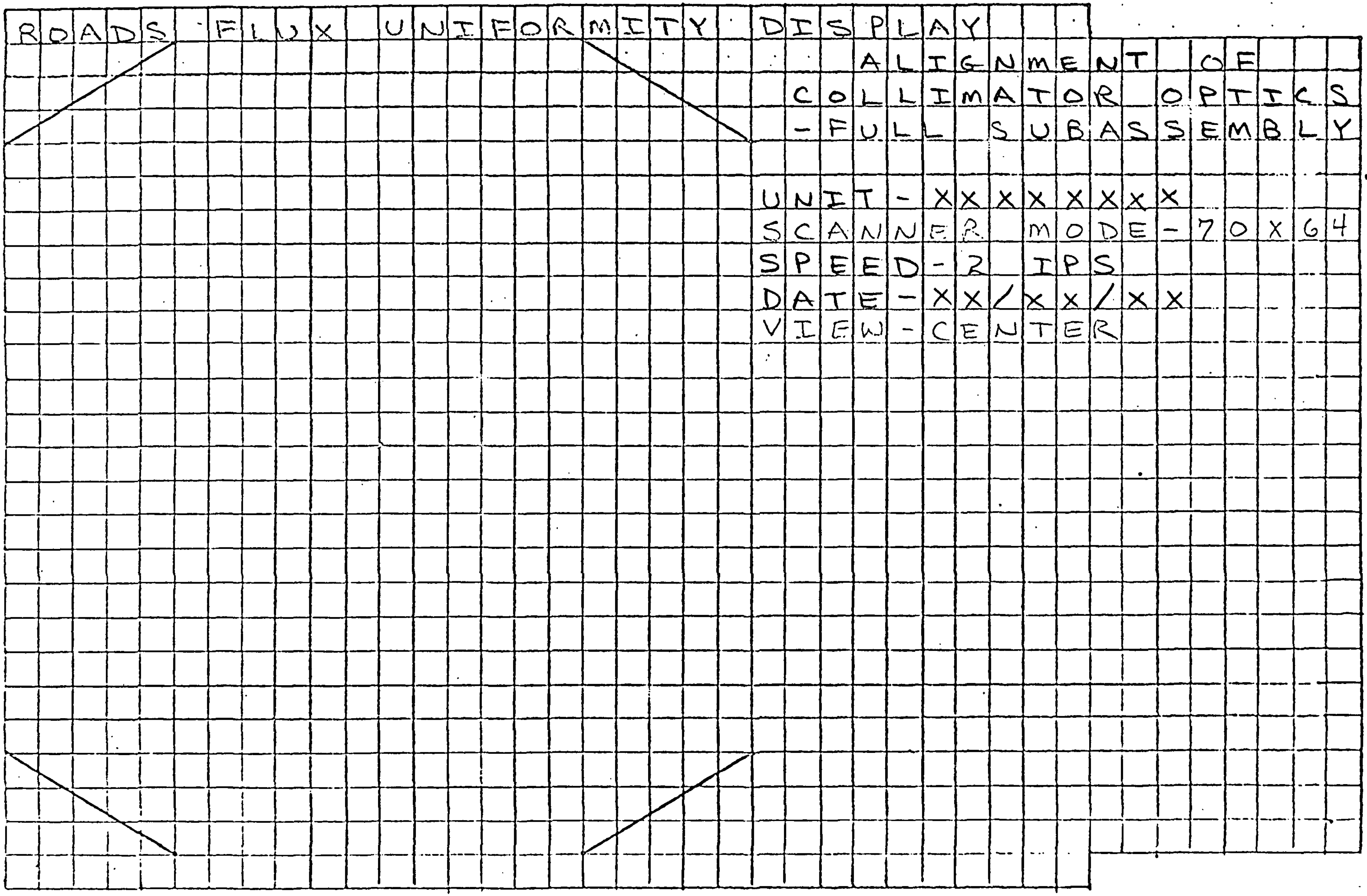
Task 1, mode 7, pg 1

Figure B-20



Task 1, mode 7, pg 2

Figure B-21



Task 1, mode 7, pg 3

Figure B-22

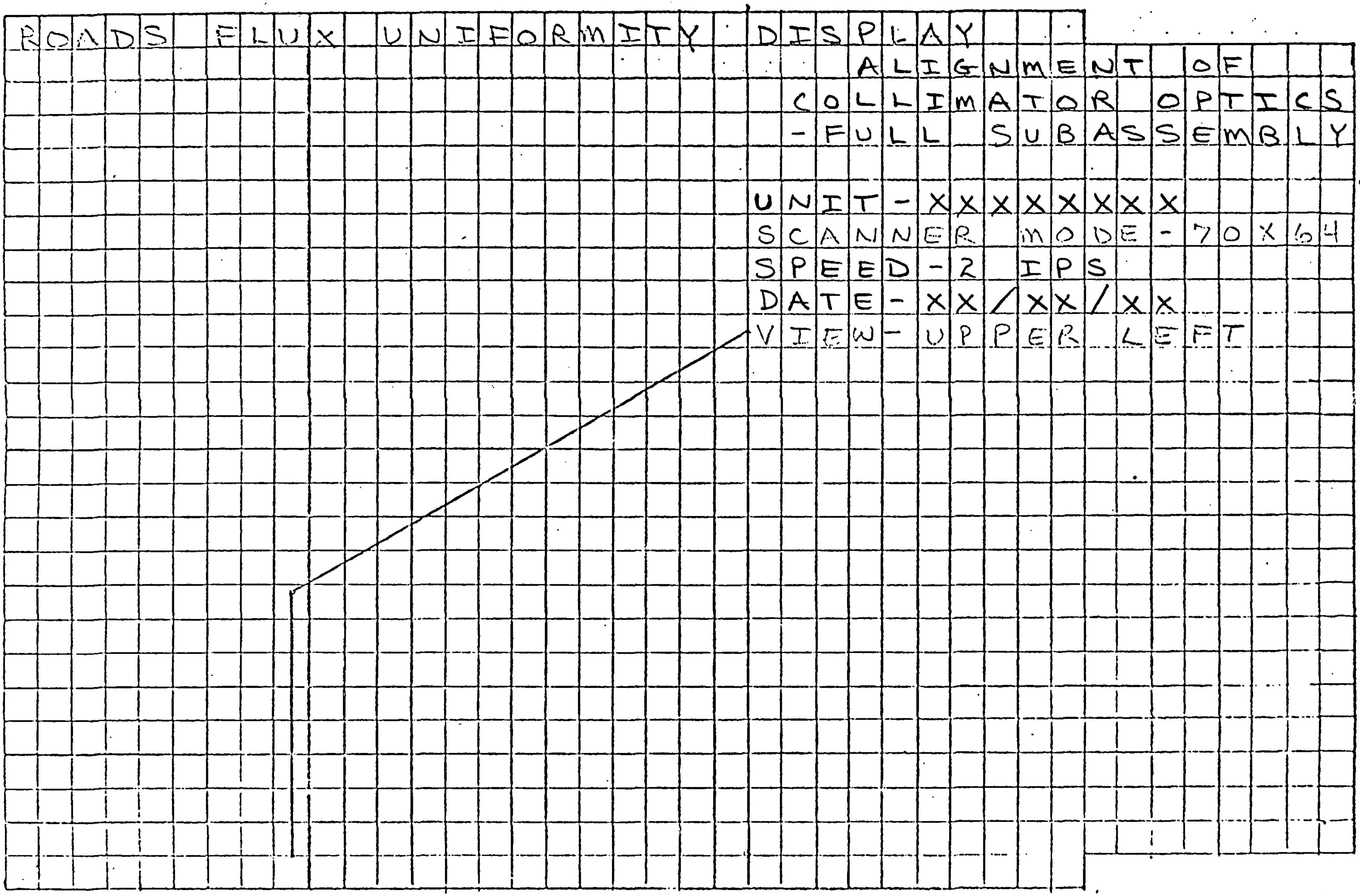


Figure B-23

Task 1, mode 7, pg 4

UL

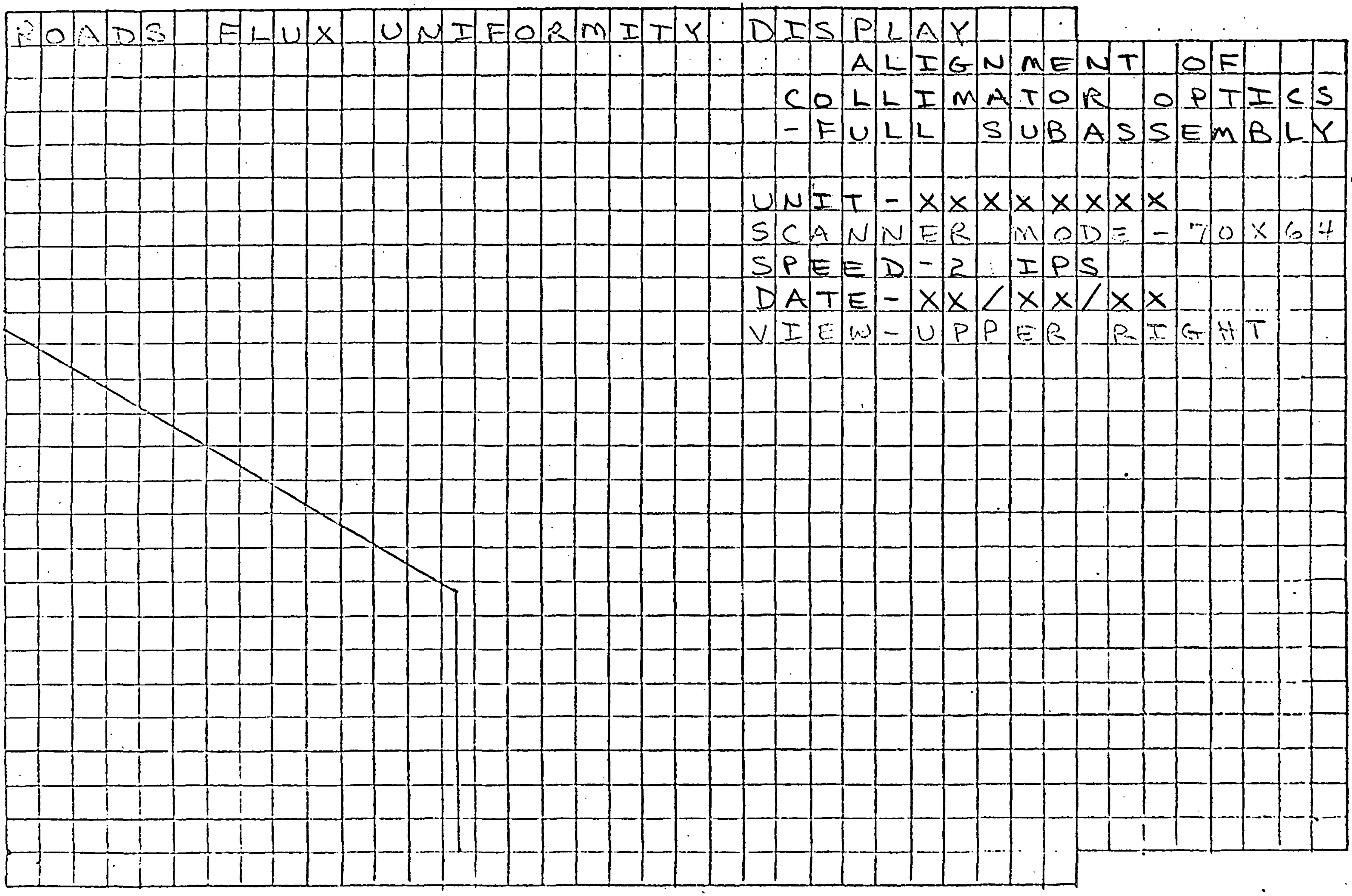


Figure B-24

Task 1, mode 7, pg 5

LR

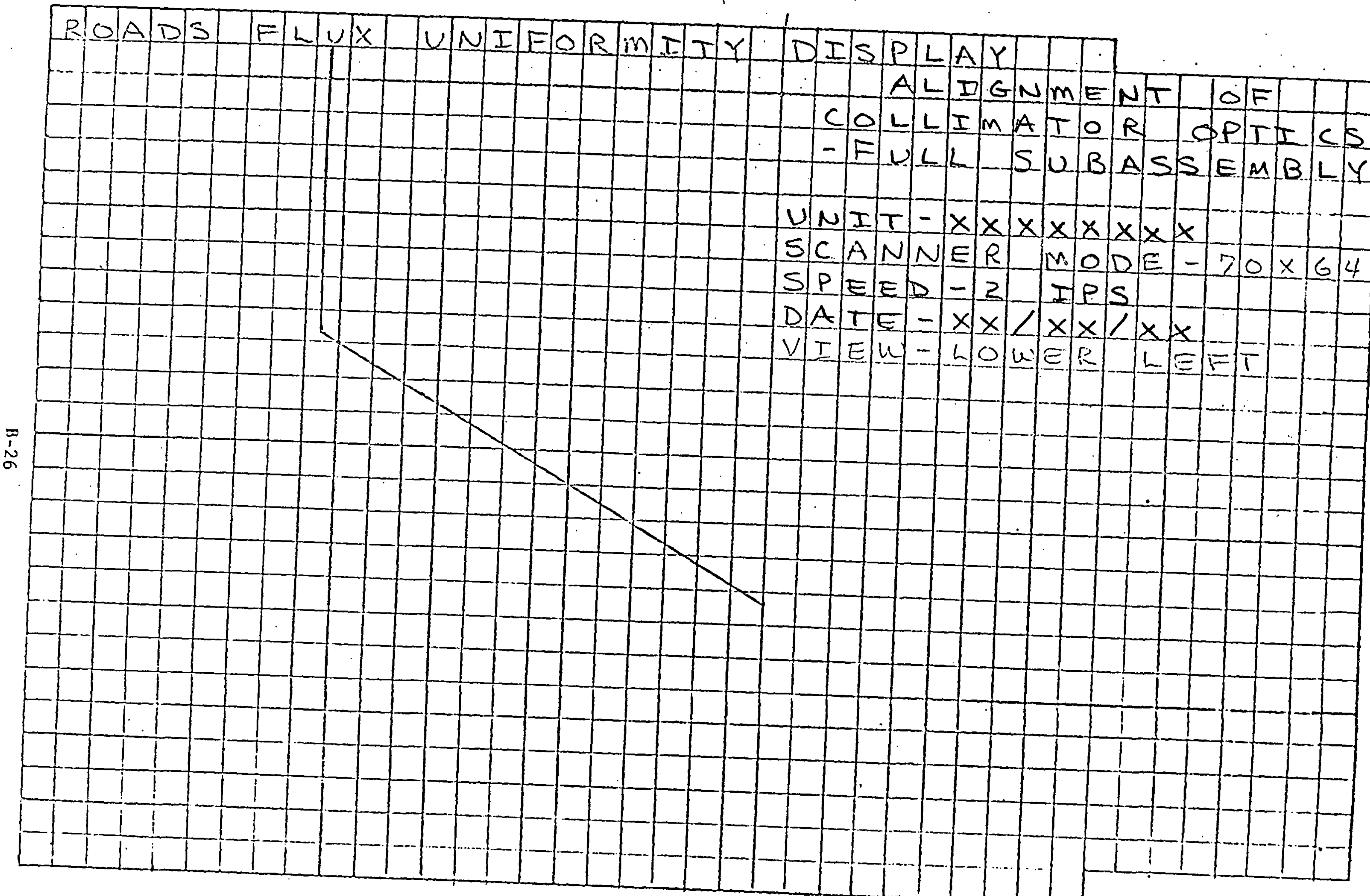
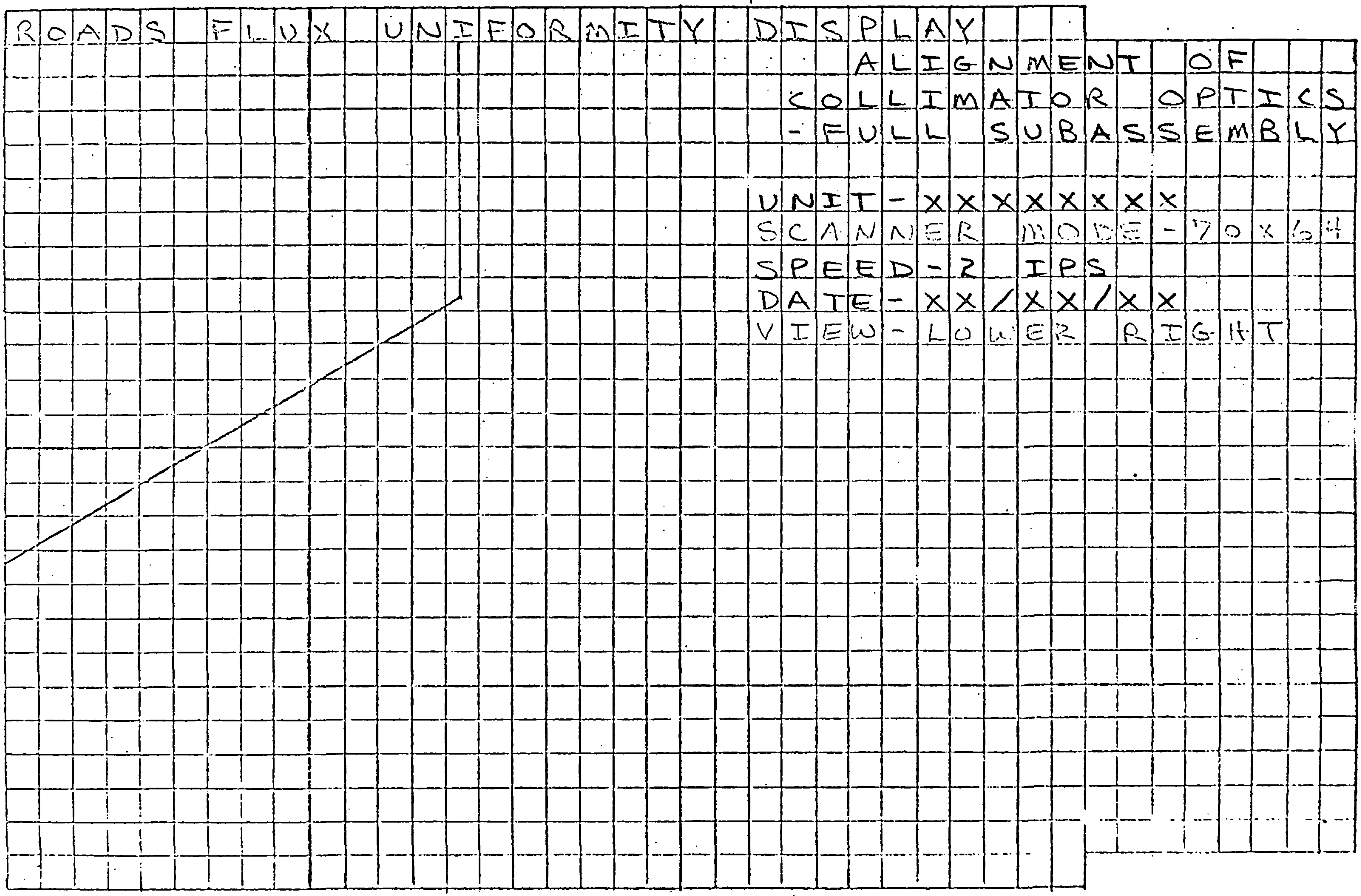


Figure B-25

Task 1, mode 7, pg 6
12



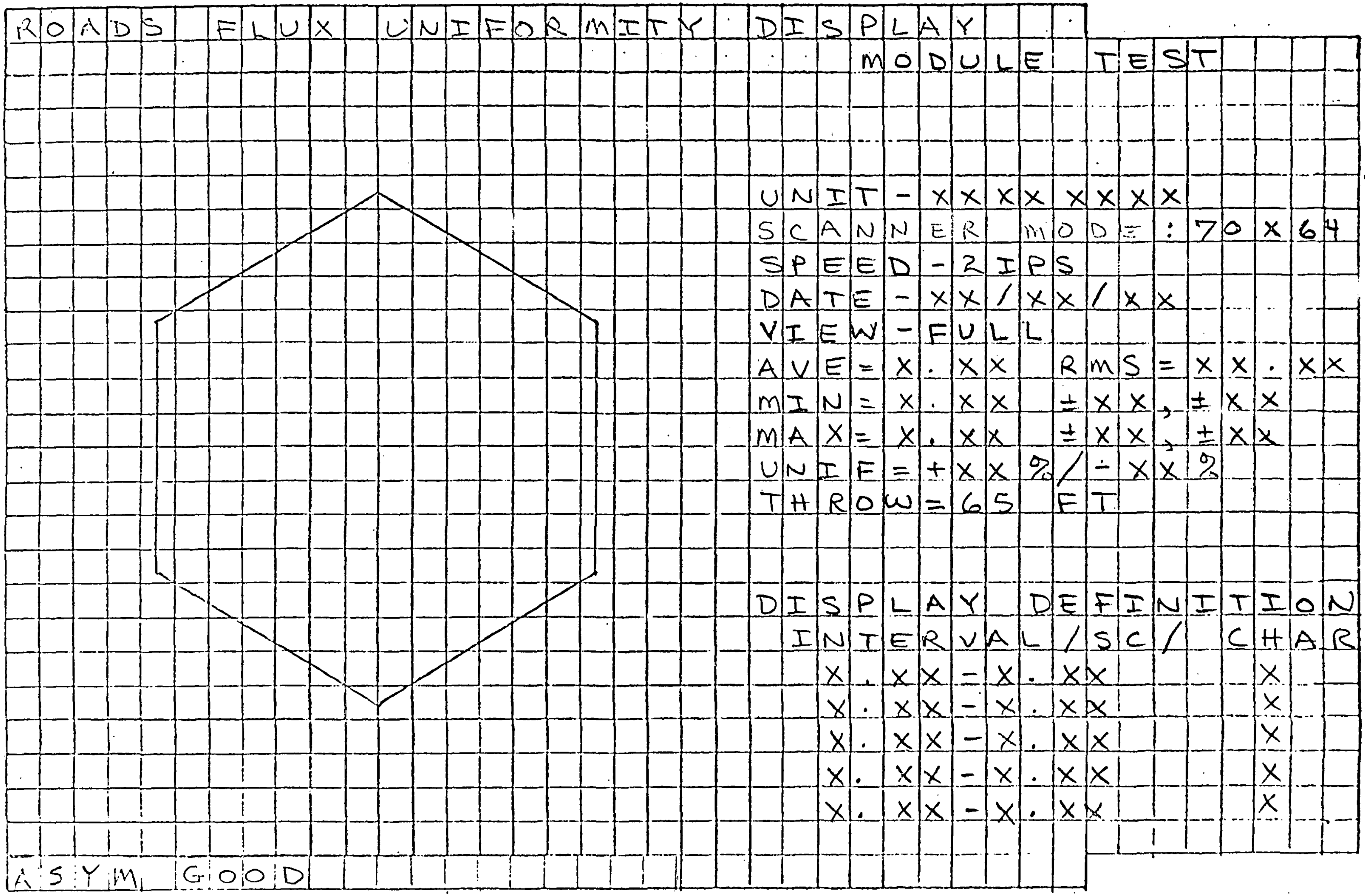
Task 1, mode 7, pg 7
LK

Figure B-26

```
  ROADS MODE 8 - MODULE TEST
                           DATE-XX/XX/XX

SETUP...
  SCANNER MODE- 54X48 OR 70X64
  SCANNER CONFIG- FINE

ROADS CONTROL...
  CSTARTS-COABCDEFGH  /MODULE ID/
          1400000OTO  /THROW/
          C300000000  /PRINTER LISTING/
          C500000000  /DATA TO MDF/

ROADS SCANNER CONTROL...
  PRESS START BUTTON TO BEGIN SCAN
   TO ABORT SCAN... PRESS RESET BUTTON
```

Figure B-27

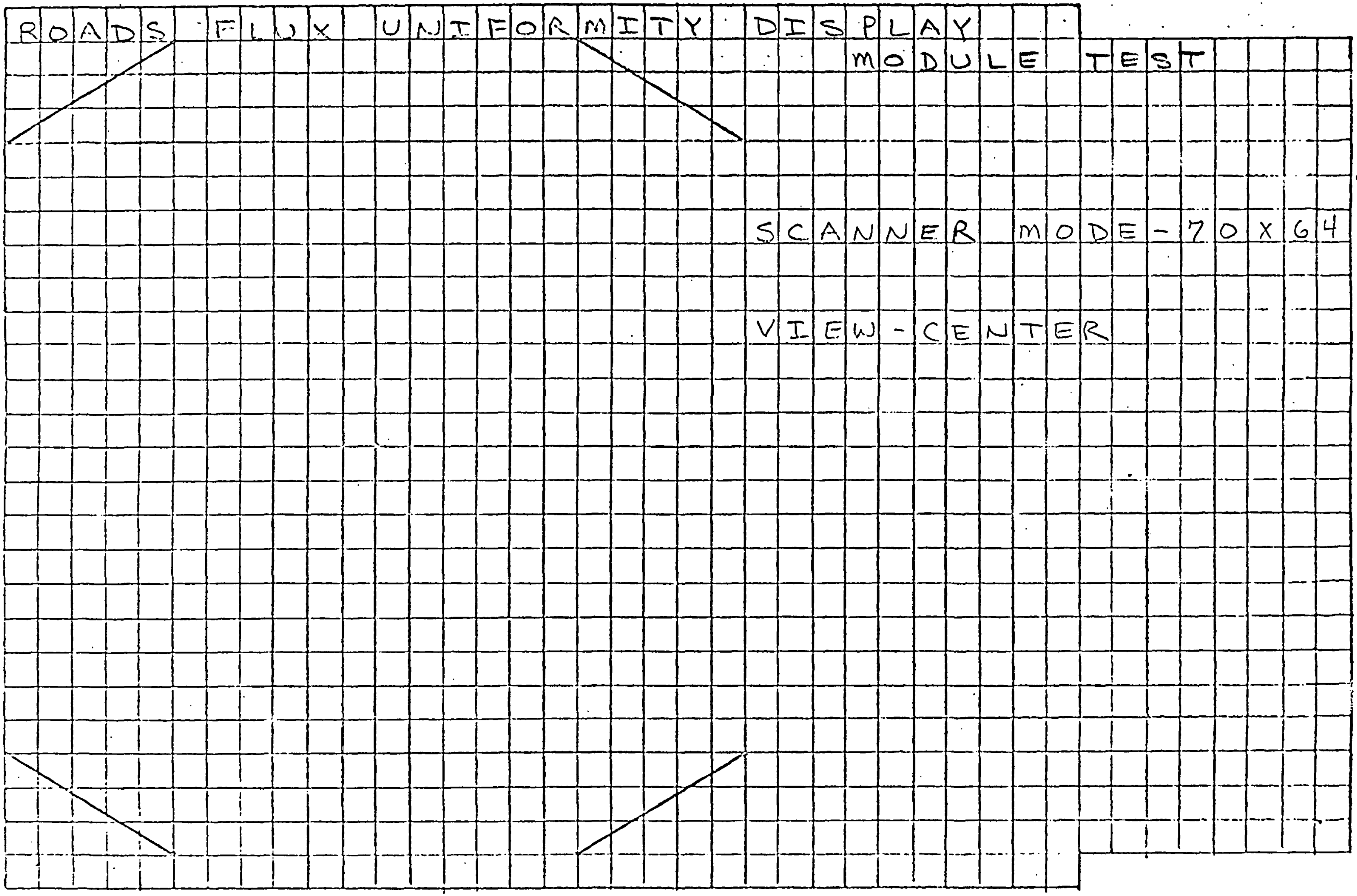
Task 1, mode 8, pg 1



Task 1, mode 8, pg 2

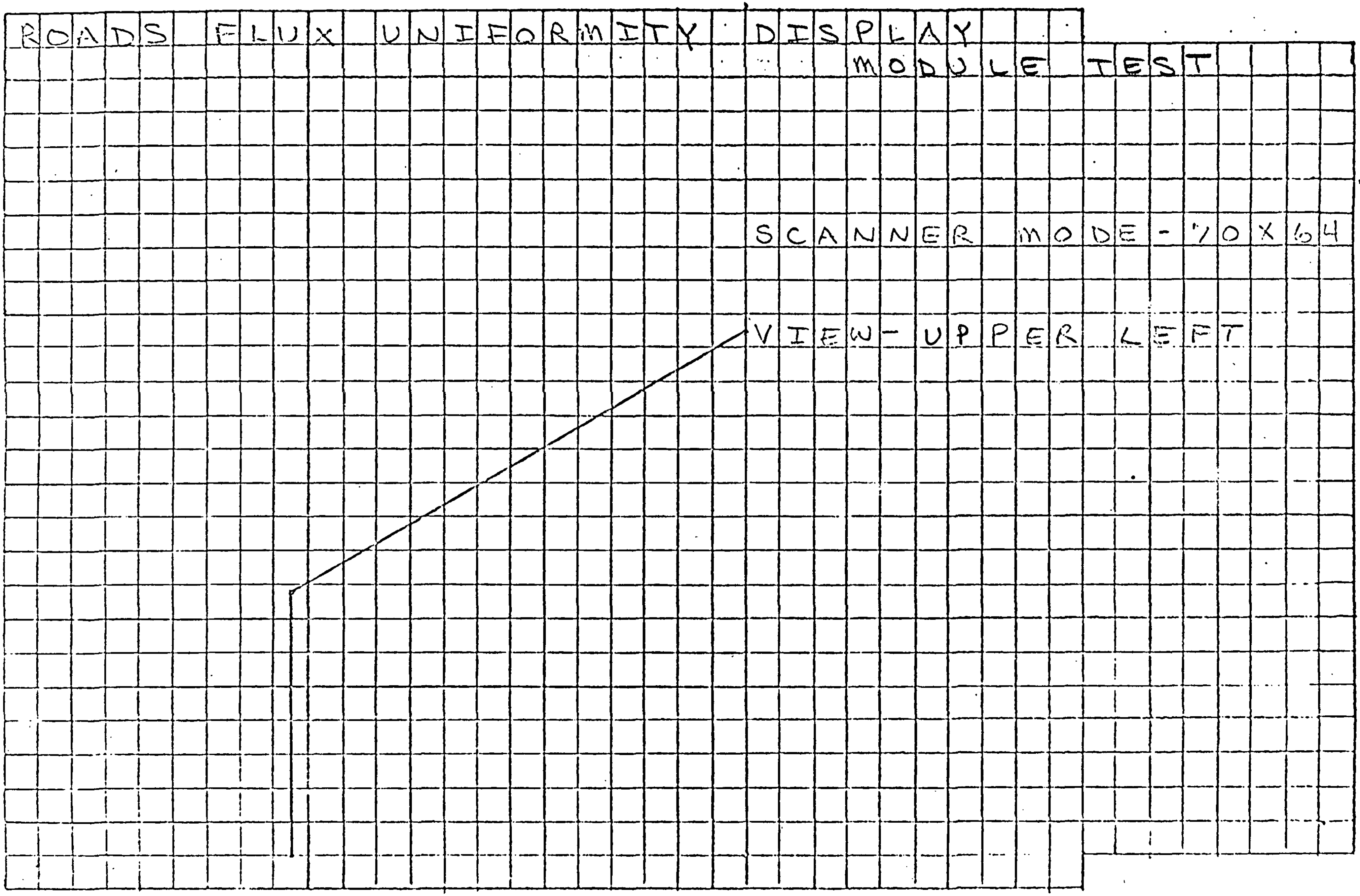
full

Figure B-28



Task 1, mode 8, pg 3

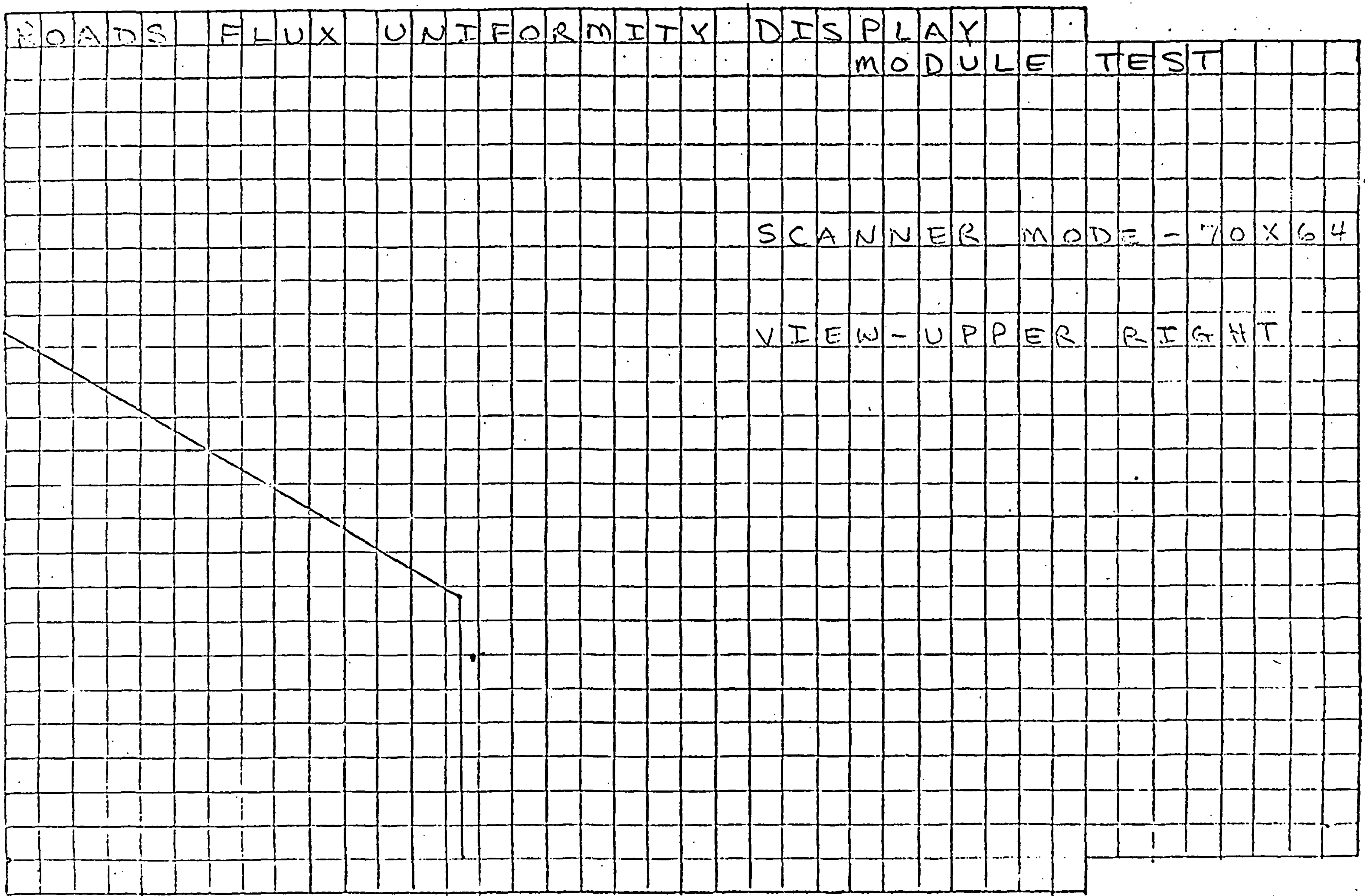
Figure B-29



Task 1, mode 8, pg 4

Figure B-30

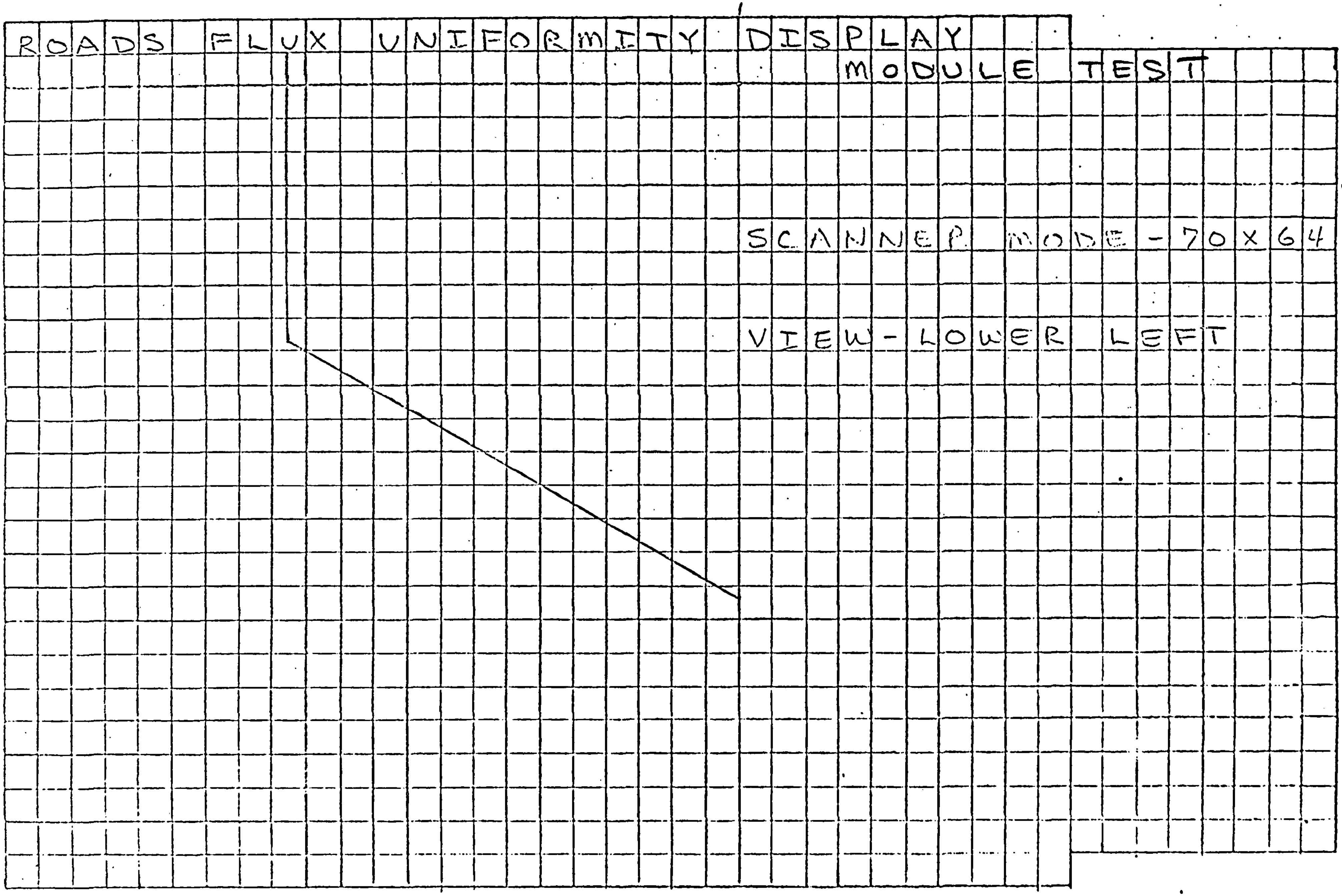
UL



Task 1, mode 8, pg 5

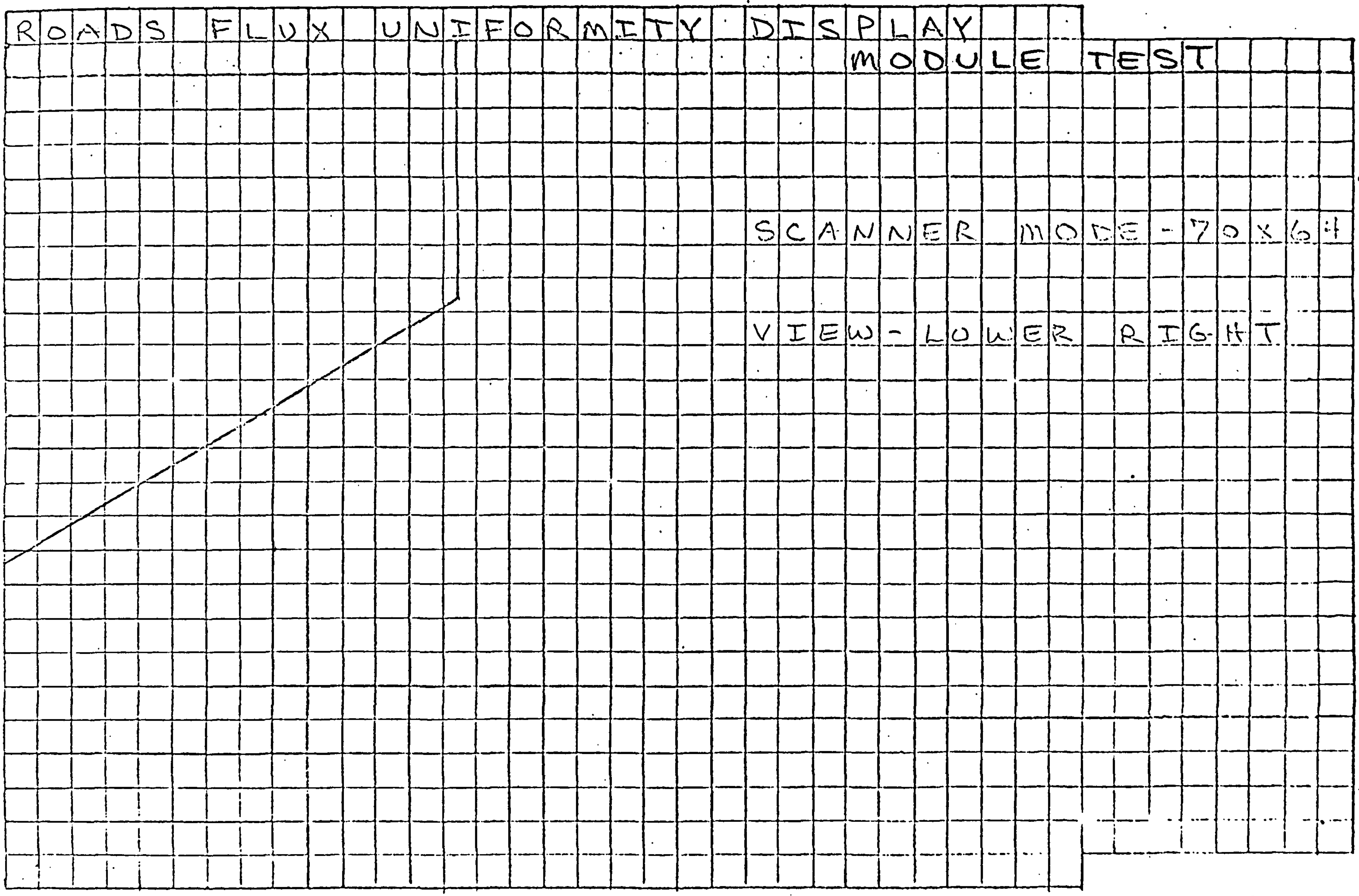
UR

Figure B-31



Task 1, mode 8, pg 6
LL

Figure B-32



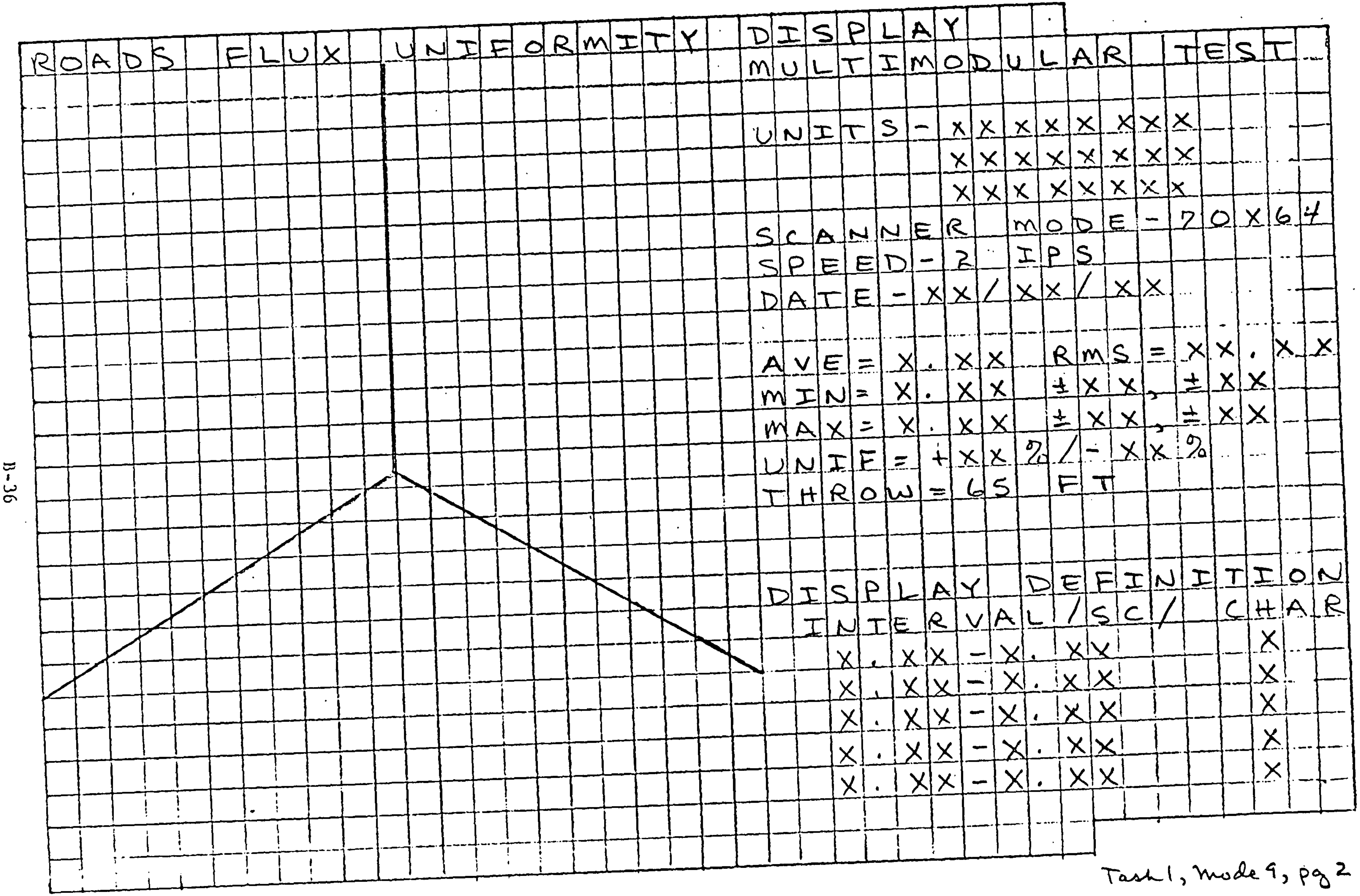
Task 1, mode 8, pg 7
LR

Figure B-33

```
ROADS MODE 9 - MULTIMODULAR TEST
                                   DATE - XX/XX/XX

SETUP...
  ALIGN SCANNER IN CHAMBER
  SCANNER MODE - 54X48 OR 70X64
  SCANNER CONFIG - FINE

ROADS CONTROL...
  CSTARTS - 11ABCDEFGH   /MODULE 1 ID/
            12ABCDEFGH   /MODULE 2 ID/
            13ABCDEFGH   /MODULE 3 ID/
            140000000TO  /THROW/
            C300000000   /PRINTER LISTING/

ROADS SCANNER CONTROL...
  PRESS START BUTTON TO BEGIN SCAN
   TO ABORT SCAN...PRESS RESET BUTTON
```

Task1, mode 9, pg 1

Figure B-34



Task 1, mode 9, pg 2

Figure B-35

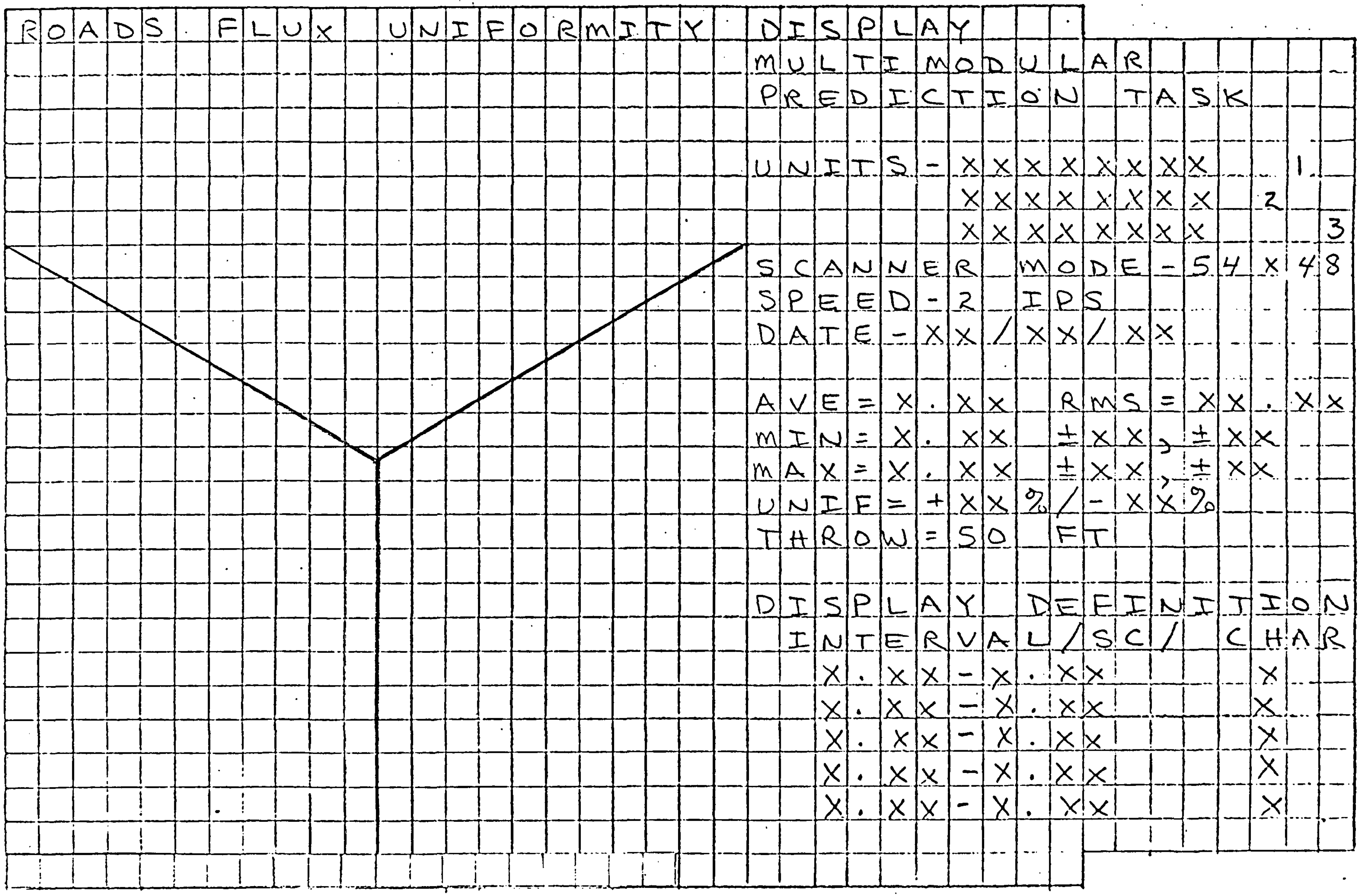


Figure B-36

Task 10 pg 1,
Orientation 0

```
ROADS FLUX UNIFORMITY DISPLAY
                         MULTI MODULAR
                         PREDICTION TASK

                         UNITS - XXXXXXXX 1
                                 XXXXXXXX  2
                                 XXXXXXXX 3
                         SCANNER MODE - 54 X 48
                         SPEED - 2 IPS
                         DATE - XX/XX/XX

                         AVE = X.XX RMS = XX.XX
                         MIN = X.XX ±XX, ±XX
                         MAX = X.XX ±XX, ±XX
                         UNIF = +XX%/-XX%
                         THROW = 50 FT

                         DISPLAY DEFINITION
                          INTERVAL/SC/ CHAR
                            X.XX-X.XX     X
                            X.XX-X.XX     X
                            X.XX-X.XX     X
                            X.XX-X.XX     X
                            X.XX-X.XX     X
```

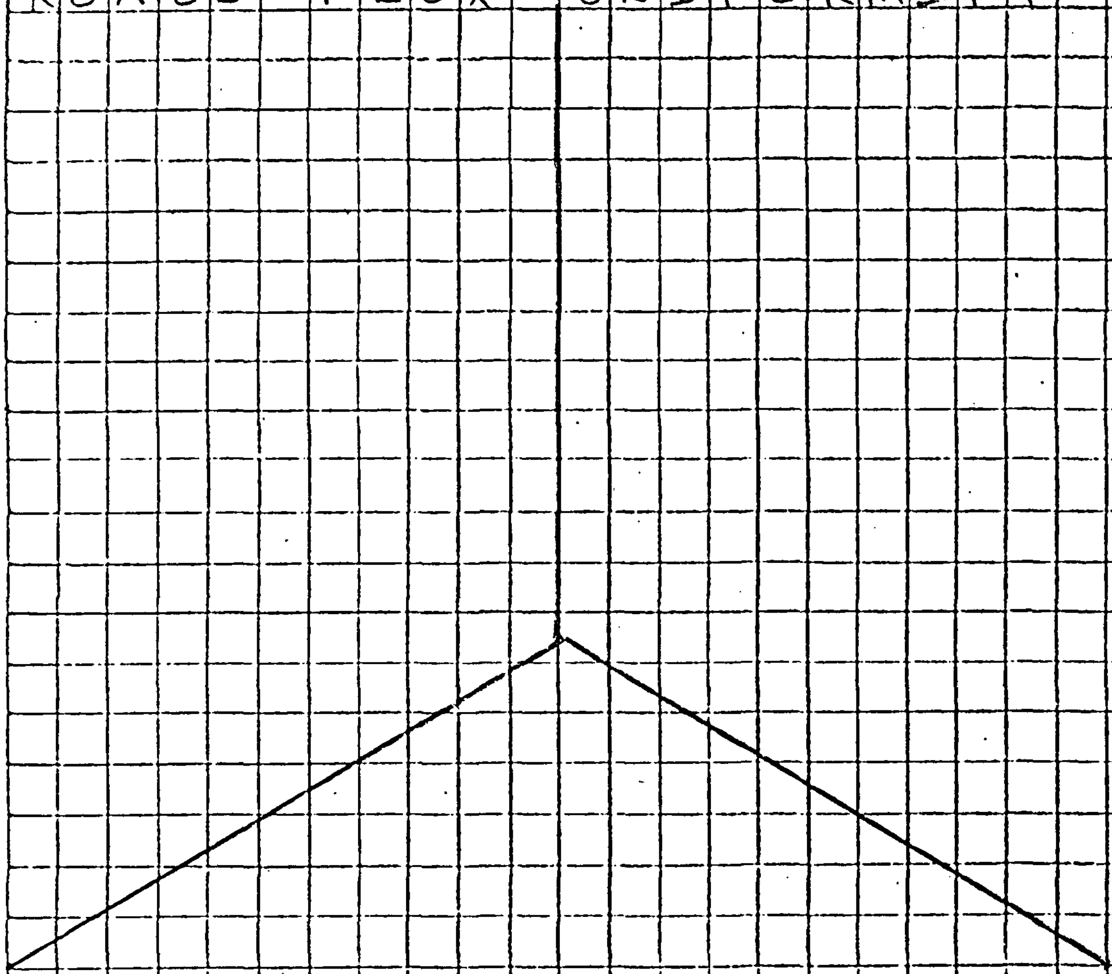


Figure B-37

Task 10, pg 1, Orientation 1

APPENDIX C

OUTLINE OF TYPICAL ROADS USAGE OPERATIONAL SEQUENCE FOR ROADS DATA COLLECTION

OUTLINE OF TYPICAL ROADS USAGE
OPERATIONAL SEQUENCE
FOR ROADS DATA COLLECTION

1. CSTART - Input CSTART with data collection mode. When the mode changes a mode-specific partition-character set is instituted.

2. The particular test or data collection mode will be described on CRT page 1. This description will include the available options and necessary input.

3. CSTART - enter CRT partition-character set if other than the nominal is desired.

4. CSTART - enter unit ID, throw, and source

5. Set scanner mode, speed and detector configuration.

6. Check to see that scanner is ready to start.

7. Push START button. The scanner will start and the data collection will begin.

8. When the data collection is complete CRT page 2 and in some cases pages 3-7 will contain pictorial representations of the collected data, statistics and indications of misalignment.

9. If the unit is satisfactorily aligned go to 13, otherwise continue.

10. Adjust unit according to the ROADS Alignment Guide.

11. Modify CRT partition-character set if desired.

12. Go to 5.

13. Add performance data to master data file (Task 5).

14. Generate printed summary on line printer (Task 3).

15. Perhaps generate tape for isointensity plots (Task 9).

APPENDIX D

NOMINAL IRRADIANCE SURFACES

The following data constitutes the nominal irradiance values and axial displacement for the various optical systems as labelled at the top of each set. The values shown represent 1/8 of the test plane and when continuously folded cover the entire test plane.

COLLECTOR REFRACTIVE OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
NO AXIAL DISPLACEMENT
AREA= 12 X12 WITH 1.5 SQUARES.

.0000	.0000	.0000	.0000
	.0000	.0000	.0000
		.0000	.0000
			1.0383

COLLECTOR REFRACTIVE OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT LENS 1, +1/8
AREA= 12 X12 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000
	.0000	.0000	.0000
		.0000	.0000
			1.0401

COLLECTOR REFRACTIVE OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT LENS 1, •1/8
AREA= 12 X12 WITH 1•5 SQUARES

•0000	•0000	•0000	•0000
	•0000	•0000	•0000
		•0000	•0000
			•8610

COLLECTOR REFLECTIVE OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
NO AXIAL DISPLACEMENT
AREA= 12 X12 WITH 1.5 SQUARES

.1353	.1043	.1377	.1551
	.1551	.2008	.2544
		.3677	.2156
			.0202

COLLECTOR REFLECTIVE OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT MIRROR 1, +1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1142	.0953	.1364	.1334
	.1334	.1885	.2816
		.3919	.3389
			.1247

COLLECTOR REFLECTIVE OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT MIRROR 1, -1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1165	.1256	.1682	.1469
	.1469	.2552	.3148
		.2526	.2081
			.0000

COLLECTOR REFLECTIVE OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT MIRROR 2, +1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1113	.1110	.1109	.1766
	.1766	.2297	.3368
		.3304	.2720
			.0094

COLLECTOR REFLECTIVE OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT MIRROR 2, -1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1000	.1302	.1310	.1749
	.1749	.1878	.2970
		.3855	.2670
			.0332

COLLECTOR COMBINED OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
NO AXIAL DISPLACEMENT
AREA= 12 X12 WITH 1.5 SQUARES

.1353	.1043	.1377	.1551
	.1551	.2008	.2544
		.3677	.2154
			1.0472

COLLECTOR COMBINED OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT LENS 1, +1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1353	.1043	.1377	.1551
	.1551	.2008	.2544
		.3677	.2154
			1.0563

COLLECTOR COMBINED OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT LENS 1, -1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1353	.1043	.1377	.1551
	.1551	.2008	.2544
		.3677	.2161
			.8789

COLLECTOR COMBINED OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT MIRROR 1, +1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1142	.0953	.1364	.1334
	.1334	.1885	.2816
		.3919	.3388
			1.1742

COLLECTOR COMBINED OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT MIRROR 1, -1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1165	.1256	.1682	.1469
	.1469	.2552	.3148
		.2526	.2081
			1.0383

COLLECTOR COMBINED OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT MIRROR 2, +1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1113	.1110	.1109	.1766
	.1766	.2297	.3368
		.3304	.2718
			1.0331

COLLECTOR COMBINED OPTICS, HALF INCH SPHERICAL SOURCE, TESTPLANE AT FIELD LENS
AXIAL DISPLACEMENT MIRROR 2, -1/8
AREA= 12 X12 WITH 1.5 SQUARES

.1000	.1302	.1310	.1749
	.1749	.1878	.2970
		.3855	.2669
			1.0760

COLLIMATOR REFRACTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
NO AXIAL DISPLACEMENT

AREA= 30 X30 WITH 1.5 SQUARES

.0000	.0000	.0000	.0042	.1436	.2813	.3856	.4212	.4459	.4597
	.0000	.0340	.2175	.3856	.4459	.5077	.5678	.6735	.7101
		.2488	.4128	.4888	.6303	.7523	.7318	.6865	.6829
			.5077	.7101	.7318	.6825	.6421	.5417	.5065
				.7037	.6638	.5065	.5835	.7509	.7838
					.5008	.7509	.7514	.7539	.7766
						.7404	.7944	.8170	.7777
							.7777	.6603	.7090
								.7334	.7294
									.8311

COLLIMATOR REFRACTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT LENS 3, +1/4
AREA= 30 X30 WITH 1.5 SQUARES

.0000	.0000	.0207	.2643	.2391	.4634	.5702	.4995	.4823	.4993
	.0479	.2637	.3477	.5702	.4823	.5884	.6173	.5814	.5552
		.4051	.5293	.5582	.6041	.5261	.5286	.5509	.5564
			.5684	.5552	.5286	.5632	.6122	.6894	.7182
				.5409	.5928	.7182	.6598	.5848	.6043
					.7261	.5848	.7514	.8329	.8098
						.8028	.7591	.6169	.6009
							.6009	.6915	.6921
								.6807	.7006
									.7857

COLLIMATOR REFRACTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT LENS 3, -1/4
AREA= 30 X30 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0000	.0358	.1022	.3054	.4349	.4759
	.0000	.0000	.0111	.1022	.4349	.4928	.5212	.5901	.6232
		.0221	.2239	.5027	.5544	.6676	.6735	.6570	.6502
			.4928	.6232	.6735	.6412	.6825	.8418	.9054
				.6614	.6571	.9054	.7454	.5531	.5776
					.9165	.5531	.8226	.8266	.7140
						.8812	.6710	.9380	.9075
							.9075	.6026	.9070
								.9838	.6984
									.8563

COLLIMATOR REFRACTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT LENS 4, +1/4
AREA= 30 X30 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0000	.0361	.1018	.3010	.4300	.4777
	.0000	.0000	.0112	.1018	.4300	.5179	.5110	.4980	.4980
		.0223	.2209	.5235	.5045	.5313	.7160	.8024	.8008
			.5179	.4930	.7160	.7675	.6639	.7746	.8332
				.7725	.6716	.8332	.7245	.5707	.5781
					.8519	.5707	.7370	.8048	.7792
						.7954	.7684	.8578	.8235
							.8235	.6943	.9412
								.9579	.7048
									.8548

COLLIMATOR REFRACTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT LENS 4, .1/4
AREA= 30 X30 WITH 1.5 SQUARES

.0000	.0000	.0199	.2648	.3290	.4124	.4890	.5457	.5749	.5935
	.0460	.2976	.3771	.4890	.5749	.6211	.5982	.5578	.5371
		.3945	.5290	.6203	.5798	.5161	.5246	.5512	.5589
			.6211	.5371	.5246	.5678	.6156	.6729	.6979
				.5394	.5976	.6979	.7066	.6723	.6701
					.7122	.6723	.6911	.7555	.7866
						.7113	.7746	.6188	.5960
							.5960	.6926	.6926
								.6804	.7007
									.7857

COLLIMATOR REFLECTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
NO AXIAL DISPLACEMENT
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0001
.0000	.0000	.0000	.0111	.0736
.0000	.0000	.0294	.0765	.1008
	.0365	.0760	.1111	.1154
		.1139	.1169	.1888
			.1963	.2694
				.2612

.0503	.0765	.0898	.1164	.1173	.1189	.1382	.1710	.1963	.2110	.2194
.0834	.1164	.1156	.1325	.1888	.2360	.2634	.2705	.2615	.2544	.2522
.1184	.1279	.1963	.2553	.2684	.2516	.2787	.3343	.3713	.3834	.3861
.1618	.2434	.2684	.2559	.3343	.3861	.3754	.3531	.4177	.4421	.4515
.2634	.2522	.3193	.3867	.3764	.4421	.4643	.4416	.3999	.3758	.3582
.2559	.3713	.3732	.4421	.4596	.3890	.3082	.3000	.3409	.3960	.4259
.3834	.3831	.4635	.3999	.2995	.3409	.4723	.5112	.4848	.4697	.4619
.3928	.4634	.3582	.3073	.4723	.4969	.4522	.4113	.3894	.3807	.3822
	.3393	.3409	.5084	.4619	.4050	.3822	.4143	.4599	.4656	.4571
		.5112	.4414	.3832	.4143	.4656	.4038	.3927	.4234	.4392
			.3807	.4477	.4222	.4061	.4483	.4057	.3760	.3783
				.4038	.4392	.4057	.3872	.3647	.2659	.2278
					.3870	.3846	.2278	.2900	.4418	.4680
						.2171	.4418	.4018	.3496	.3353
							.3653	.3167	.2581	.2478
								.2478	.2660	.2714
									.2549	.2293
										.2448

COLLIMATOR REFLECTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT MIRROR 3, +1/4
AREA= 54 X43 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0034
	.0000	.0000	.0075	.0621
		.0089	.0808	.1169
			.1175	.1224
				.2337

.0000	.0000	.0008	.0101	.0340	.0883	.1149	.1182	.1175	.1187	.1181
.0001	.0101	.0521	.1112	.1169	.1157	.1167	.1312	.1557	.1795	.1923
.0268	.1064	.1175	.1141	.1377	.2048	.2507	.2734	.2829	.2913	.2953
.1187	.1147	.1377	.2252	.2734	.2953	.3052	.3087	.3036	.3047	.3082
.1167	.1923	.2694	.2987	.3085	.3047	.3384	.4087	.4724	.5039	.5213
.2252	.2829	.3059	.3047	.3678	.4878	.5559	.5459	.5154	.4832	.4687
.2913	.3087	.3283	.4724	.5570	.5154	.4514	.4647	.4928	.4979	.4970
.3072	.3515	.5213	.5398	.4514	.4846	.4940	.4674	.4465	.4380	.4386
	.5373	.5154	.4566	.4970	.4630	.4386	.4808	.5435	.5527	.5427
		.4647	.4888	.4416	.4808	.5527	.4742	.4579	.4962	.5125
			.4380	.5266	.4987	.4755	.5110	.4214	.3818	.3869
				.4742	.5125	.4214	.4051	.4310	.3605	.3231
					.3943	.4372	.3231	.3287	.3993	.4132
						.3043	.3993	.4021	.3818	.3697
							.3900	.3568	.3283	.3218
								.3218	.3340	.3625
									.3234	.2612
										.3346

COLLIMATOR REFLECTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT MIRROR 3, -1/4
AREA= 54 X43 WITH 1.5 SQUARES

.0000	.0016	.0214	.0842	.0748
.0034	.0365	.0816	.0989	.1368
.0428	.0769	.1184	.1212	.1444
	.1244	.1143	.1730	.2574
		.1823	.2616	.2292
			.2302	.3388
				.3250

.1343	.1212	.1238	.1905	.2438	.2633	.2523	.2326	.2302	.2383	.2454
.1164	.1905	.2540	.2572	.2292	.2653	.3250	.3426	.3336	.3235	.3194
.2370	.2611	.2302	.3028	.3413	.3169	.3458	.4028	.4305	.4308	.4238
.2365	.2774	.3413	.3192	.4028	.4238	.3679	.3795	.4572	.5229	.5519
.3250	.3194	.3890	.4134	.3674	.5229	.5976	.5309	.4547	.4350	.4277
.3192	.4305	.3630	.5229	.5776	.4429	.4207	.4355	.4601	.4746	.4757
.4308	.3795	.5969	.4547	.4241	.4601	.4656	.3786	.3247	.3265	.3408
.3994	.5914	.4277	.4409	.4656	.3354	.3647	.4972	.5279	.5088	.4891
	.4224	.4601	.4062	.3408	.5136	.4891	.4470	.4303	.4166	.4062
		.3786	.3968	.5228	.4470	.4166	.3765	.3748	.3949	.4002
			.5088	.4361	.3841	.3849	.3882	.3128	.2836	.2838
				.3765	.4002	.3128	.2929	.3274	.3056	.2942
					.2928	.3228	.2942	.3484	.3930	.3695
						.2923	.3930	.2596	.2635	.3045
							.2401	.3164	.2269	.2040
								.2040	.2065	.1677
									.1877	.2377
										.1531

COLLIMATOR REFLECTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT MIRROR 4, +1/4
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0016	.0213	.0345	.0762
.0034	.0362	.0838	.0905	.1175
.0424	.0797	.1025	.1126	.1571
	.1063	.1118	.1836	.2118
		.1914	.2111	.2608
			.2663	.3320
				.3398

.1130	.1126	.1335	.1980	.2151	.2125	.2272	.2487	.2663	.2775	.2840
.1226	.1980	.2129	.2234	.2608	.2975	.3248	.3367	.3375	.3357	.3350
.2154	.2201	.2663	.3156	.3377	.3348	.3460	.3659	.3828	.3908	.3939
.2427	.3040	.3377	.3373	.3659	.3939	.4116	.4381	.4756	.4992	.5081
.3248	.3350	.3602	.3967	.4293	.4992	.5211	.4948	.4682	.4642	.4654
.3373	.3828	.4170	.4992	.5126	.4648	.4765	.4851	.4860	.4777	.4691
.3908	.4381	.5212	.4682	.4807	.4860	.4482	.3682	.3353	.3465	.3681
.4495	.5183	.4654	.4854	.4482	.3390	.4007	.5456	.5476	.4934	.4599
	.4682	.4860	.3911	.3681	.5580	.4599	.4178	.4442	.4493	.4462
		.3682	.4405	.5248	.4178	.4493	.4188	.3885	.3710	.3637
			.4934	.4345	.4307	.3794	.3514	.3404	.3271	.3106
				.4188	.3637	.3404	.2895	.2745	.3381	.3780
					.3349	.2694	.3780	.3736	.3026	.2981
						.4009	.3026	.3220	.3126	.2915
							.3236	.2728	.2509	.2380
								.2380	.2005	.1650
									.1894	.2373
										.1531

COLLIMATOR REFLECTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT MIRROR 4, -1/4
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0094
	.0000	.0000	.0207	.0684
		.0245	.0796	.1236
			.1264	.1527
				.2011

.0000	.0000	.0022	.0278	.0516	.0845	.1060	.1185	.1264	.1320	.1344
.0003	.0278	.0626	.1020	.1236	.1385	.1476	.1584	.1686	.1774	.1823
.0468	.0978	.1264	.1437	.1614	.1873	.2087	.2288	.2499	.2674	.2797
.1158	.1402	.1614	.1970	.2288	.2797	.3427	.3590	.3355	.3141	.3062
.1476	.1823	.2228	.2934	.3595	.3141	.3147	.3942	.4735	.5078	.5245
.1970	.2499	.3504	.3141	.3453	.4913	.5519	.5369	.5126	.4882	.4782
.2674	.3590	.3065	.4735	.5503	.5126	.4684	.5002	.5339	.5371	.5349
.3542	.3275	.5245	.5322	.4684	.5256	.5293	.4731	.4208	.3847	.3786
	.5387	.5126	.4871	.5349	.4608	.3786	.4381	.5694	.6108	.6124
		.5002	.5193	.3996	.4381	.6108	.5342	.4608	.4322	.4276
			.3847	.5277	.5717	.4439	.4288	.4706	.4697	.4496
				.5342	.4276	.4706	.4176	.3447	.3599	.3769
					.4757	.3564	.3769	.3534	.3236	.3388
						.3858	.3236	.4193	.4139	.3701
							.4325	.3394	.3401	.3349
								.3349	.3141	.3459
									.3180	.2619
										.3344

COLLIMATOR COMBINED OPTICS, DUMMY COLLECTOR, 50 FT THROW
NO AXIAL DISPLACEMENT
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0001
.0000	.0000	.0000	.0111	.0736
.0000	.0000	.0294	.0765	.1008
	.0365	.0760	.1111	.1154
		.1139	.1169	.1888
			.1963	.2694
				.2612

.0503	.0765	.0898	.1164	.1173	.1189	.1382	.1710	.1963	.2110	.2194
.0834	.1164	.1156	.1325	.1838	.2360	.2634	.2705	.2615	.2544	.2522
.1184	.1279	.1963	.2553	.2684	.2516	.2787	.3343	.3713	.3833	.3861
.1618	.2434	.2684	.2559	.3343	.3861	.3754	.3831	.4177	.4420	.4515
.2634	.2522	.3193	.3667	.3764	.4420	.4643	.4418	.4001	.3758	.3580
.2559	.3713	.3733	.4420	.4597	.3892	.3074	.2995	.3425	.3996	.4303
.3833	.3831	.4635	.4001	.2987	.3425	.4772	.4963	.4715	.4717	.4730
.3928	.4634	.3580	.3073	.4772	.4793	.4759	.5274	.5811	.6358	.6686
	.3389	.3425	.4995	.4730	.5440	.6686	.7943	.8791	.9132	.9200
		.4963	.4826	.6061	.7943	.9132	.9137	.9786	1.0954	1.1489
			.6358	.8550	.9148	1.0344	1.2011	1.1379	1.0626	1.0609
				.9137	1.1489	1.1379	1.0690	1.0070	.8080	.7341
					1.0910	1.0480	.7341	.8743	1.1928	1.2512
						.7174	1.1928	1.1530	1.1038	1.1120
							1.1060	1.1110	1.0750	1.0256
								1.0256	.9261	.9802
									.9884	.9586
										1.0760

COLLIMATOR COMBINED OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT LENS 3, +1/4
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0001
.0000	.0000	.0000	.0111	.0736
.0000	.0000	.0294	.0765	.1008
	.0365	.0760	.1111	.1154
		.1139	.1169	.1888
			.1963	.2694
				.2612

.0503	.0765	.0898	.1164	.1173	.1189	.1382	.1710	.1963	.2110	.2194
.0834	.1164	.1156	.1325	.1888	.2360	.2634	.2705	.2615	.2544	.2522
.1184	.1279	.1963	.2553	.2684	.2516	.2787	.3343	.3713	.3834	.3861
.1618	.2434	.2684	.2559	.3343	.3861	.3753	.3830	.4180	.4425	.4520
.2634	.2522	.3193	.3666	.3763	.4425	.4643	.4400	.3985	.3757	.3594
.2559	.3713	.3732	.4425	.4587	.3881	.3137	.3063	.3256	.3685	.3981
.3834	.3830	.4639	.3985	.3059	.3256	.4559	.5866	.6777	.7077	.7072
.3929	.4629	.3594	.3091	.4559	.6528	.6964	.6400	.7034	.8019	.8560
	.3420	.3256	.5490	.7072	.6485	.8560	.9734	.9561	.9508	.9604
		.5866	.6790	.7488	.9734	.9508	.9946	1.0080	1.0033	.9940
			.8019	.9689	.9844	1.0081	.9747	.9355	.9283	.9339
				.9946	.9940	.9355	.9467	.9795	.9555	.9421
					.9294	.9755	.9421	.9584	1.0263	1.0660
						.9389	1.0263	1.1548	1.1810	1.1446
							1.1692	1.0764	.8750	.8487
								.8487	.9575	.9632
									.9359	.9297
										1.0305

COLLIMATOR COMBINED OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT LENS 3, .1/4
AREA= 54 X43 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0001
.0000	.0000	.0000	.0111	.0736
.0000	.0000	.0294	.0765	.1008
	.0365	.0760	.1111	.1154
		.1139	.1169	.1868
			.1963	.2694
				.2612

.0503	.0765	.0898	.1164	.1173	.1189	.1382	.1710	.1963	.2110	.2194
.0834	.1164	.1156	.1325	.1888	.2360	.2634	.2705	.2615	.2544	.2522
.1184	.1279	.1963	.2553	.2684	.2516	.2787	.3343	.3713	.3834	.3861
.1618	.2434	.2684	.2559	.3343	.3861	.3754	.3831	.4177	.4421	.4515
.2634	.2522	.3193	.3867	.3764	.4421	.4643	.4416	.3999	.3758	.3582
.2559	.3713	.3732	.4421	.4596	.3890	.3082	.3001	.3408	.3958	.4257
.3834	.3831	.4635	.3999	.2996	.3408	.4722	.5116	.4859	.4707	.4614
.3928	.4634	.3582	.3074	.4722	.4977	.4498	.4118	.3897	.3871	.4015
	.3393	.3408	.5087	.4614	.4087	.4015	.5359	.7748	.8929	.9219
		.5116	.4376	.3836	.5359	.8929	.8936	.9164	1.0141	1.0624
			.3671	.6909	.9167	.9621	1.1156	1.0804	1.0349	1.0276
				.8936	1.0624	1.0804	1.0237	1.0519	1.1044	1.1237
					1.0503	1.0401	1.1237	1.0528	.9930	1.0343
						1.1262	.9930	1.2287	1.1704	1.0443
							1.2493	.9894	1.1975	1.1534
								1.1534	.8688	1.1818
									1.2355	.9285
										1.1013

COLLIMATOR COMBINED OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT LENS 4, +1/4
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0001
.0000	.0000	.0000	.0111	.0736
.0000	.0000	.0294	.0765	.1008
	.0365	.0760	.1111	.1154
		.1139	.1169	.1888
			.1963	.2694
				.2612

.0503	.0765	.0898	.1164	.1173	.1189	.1382	.1710	.1963	.2110	.2194
.0834	.1164	.1156	.1325	.1888	.2360	.2634	.2705	.2615	.2544	.2522
.1184	.1279	.1963	.2553	.2684	.2516	.2787	.3343	.3713	.3834	.3861
.1615	.2434	.2684	.2559	.3343	.3861	.3754	.3831	.4177	.4421	.4515
.2634	.2522	.3193	.3867	.3764	.4421	.4643	.4416	.3999	.3758	.3582
.2559	.3713	.3732	.4421	.4596	.3890	.3082	.3001	.3408	.3958	.4257
.3834	.3831	.4635	.3999	.2996	.3408	.4722	.5116	.4860	.4707	.4613
.3928	.4634	.3582	.3074	.4722	.4978	.4496	.4116	.3900	.3880	.4026
	.3393	.3408	.5087	.4613	.4086	.4026	.5343	.7685	.8882	.9254
		.5116	.4374	.3843	.5343	.3882	.9215	.9045	.9157	.9316
			.3880	.6856	.9408	.9076	.9802	1.1301	1.1780	1.1733
				.9215	.9316	1.1301	1.1455	1.0339	1.0386	1.0533
					1.1637	1.0552	1.0533	1.0296	1.0120	1.0356
						1.0623	1.0120	1.1403	1.1528	1.1128
							1.1635	1.0857	1.1167	1.0706
								1.0706	.9607	1.2144
									1.2112	.9344
										1.0999

COLLIMATOR COMBINED OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT LENS 4, -1/4
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0001
.0000	.0000	.0000	.0111	.0736
.0000	.0000	.0294	.0765	.1008
	.0365	.0760	.1111	.1154
		.1139	.1169	.1888
			.1963	.2694
				.2612

.0503	.0765	.0898	.1164	.1173	.1189	.1382	.1710	.1963	.2110	.2194
.0834	.1164	.1156	.1325	.1838	.2360	.2634	.2705	.2615	.2544	.2522
.1184	.1279	.1963	.2553	.2654	.2516	.2787	.3343	.3713	.3834	.3861
.1618	.2434	.2684	.2559	.3343	.3861	.3753	.3830	.4179	.4424	.4519
.2634	.2522	.3193	.3866	.3763	.4424	.4643	.4401	.3987	.3757	.3593
.2559	.3713	.3732	.4424	.4568	.3882	.3130	.3058	.3271	.3716	.4017
.3834	.3830	.4638	.3987	.3052	.3271	.4598	.5741	.6614	.7030	.7182
.3929	.4630	.3593	.3091	.4598	.6352	.7278	.7289	.7519	.7772	.7962
	.3417	.3271	.5419	.7182	.7359	.7962	.9015	1.0046	1.0413	1.0517
		.5741	.7315	.7624	.9015	1.0413	1.0249	.9910	.9815	.9765
			.7772	.9749	1.0431	.9862	.9640	.9314	.9287	.9363
				1.0249	.9765	.9314	.9513	.9821	.9410	.9241
					.9279	.9799	.9241	1.0026	1.1153	1.1326
						.9257	1.1153	1.0919	1.1070	1.1231
							1.0784	1.0909	.8768	.8442
								.8442	.9585	.9637
									.9357	.9298
										1.0305

COLLIMATOR COMBINED OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT MIRROR 3, +1/4
AREA= 54 X43 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0034
	.0000	.0000	.0075	.0621
		.0089	.0808	.1169
			.1175	.1224
				.2337

.0000	.0000	.0008	.0101	.0340	.0883	.1149	.1182	.1175	.1187	.1181
.0001	.0101	.0521	.1112	.1169	.1157	.1167	.1312	.1557	.1795	.1923
.0268	.1064	.1175	.1141	.1377	.2046	.2507	.2734	.2829	.2913	.2953
.1157	.1147	.1377	.2252	.2734	.2953	.3052	.3087	.3035	.3046	.3082
.1167	.1923	.2694	.2987	.3085	.3046	.3384	.4089	.4727	.5040	.5212
.2252	.2829	.3059	.3046	.3679	.4881	.5549	.5453	.5174	.4870	.4731
.2913	.3087	.3283	.4727	.5559	.5174	.4560	.4506	.4805	.4997	.5070
.3072	.3515	.5212	.5399	.4560	.4682	.5159	.5831	.6418	.6945	.7258
	.5368	.5174	.4480	.5070	.6023	.7258	.8598	.9611	1.0005	1.0063
		.4506	.5279	.6662	.8598	1.0005	.9847	1.0434	1.1675	1.2216
			.6945	.9329	.9921	1.1031	1.2640	1.1538	1.0680	1.0695
				.9847	1.2216	1.1538	1.0674	1.0731	.9018	.8293
					1.0981	1.1012	.8293	.9126	1.1503	1.1968
						.8051	1.1503	1.1531	1.1362	1.1468
							1.1306	1.1512	1.1447	1.1000
								1.1000	.9940	1.0702
									1.0582	.9899
										1.1658

COLLIMATOR REFRACTIVE OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT MIRROR 3, -1/4
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0016	.0214	.0842	.0748
.0034	.0365	.0816	.0989	.1368
.0426	.0769	.1184	.1212	.1444
	.1244	.1143	.1730	.2574
		.1823	.2616	.2292
			.2302	.3368
				.3250

.1343	.1212	.1238	.1905	.2438	.2633	.2523	.2326	.2302	.2383	.2454
.1164	.1905	.2540	.2572	.2292	.2653	.3250	.3426	.3336	.3235	.3194
.2370	.2611	.2302	.3028	.3413	.3169	.3458	.4028	.4305	.4308	.4238
.2365	.2774	.3413	.3192	.4028	.4238	.3679	.3795	.4571	.5228	.5518
.3250	.3194	.3890	.4134	.3674	.5228	.5976	.5311	.4548	.4350	.4276
.3192	.4305	.3630	.5228	.5777	.4430	.4201	.4351	.4614	.4770	.4785
.4303	.3795	.5969	.4548	.4235	.4614	.4684	.3699	.3174	.3273	.3454
.3994	.5914	.4276	.4408	.4684	.3255	.3778	.6118	.7277	.7690	.7770
	.4221	.4614	.4009	.3454	.6556	.7770	.8260	.8501	.8641	.8678
		.3699	.4258	.7533	.8260	.8641	.8850	.9619	1.0678	1.1101
			.7690	.8447	.8744	1.0145	1.1407	1.0449	.9700	.9665
				.8850	1.1101	1.0449	.9753	.9694	.8476	.8014
					.9967	.9866	.8014	.9294	1.1426	1.1558
						.7941	1.1426	1.0133	1.0137	1.0783
							.9796	1.1114	1.0454	.9800
								.9800	.8677	.8777
									.9197	.9684
										.9832

COLLIMATOR COMBINED OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT MIRROR 4, +1/4
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0016	.0213	.0845	.0762
.0034	.0362	.0838	.0905	.1175
.0424	.0797	.1025	.1126	.1571
	.1063	.1118	.1836	.2118
		.1914	.2111	.2608
			.2663	.3320
				.3398

.1130	.1126	.1335	.1980	.2151	.2125	.2272	.2487	.2663	.2775	.2840
.1226	.1980	.2129	.2234	.2608	.2975	.3248	.3367	.3375	.3357	.3350
.2154	.2201	.2663	.3156	.3377	.3348	.3460	.3659	.3828	.3908	.3939
.2427	.3040	.3377	.3373	.3659	.3939	.4116	.4381	.4756	.4992	.5081
.3248	.3350	.3602	.3967	.4293	.4992	.5211	.4949	.4683	.4643	.4653
.3373	.3828	.4170	.4992	.5127	.4650	.4760	.4848	.4871	.4797	.4715
.3903	.4381	.5211	.4683	.4801	.4871	.4507	.3607	.3296	.3478	.3716
.4495	.5183	.4653	.4855	.4507	.3307	.4105	.6572	.7534	.7610	.7529
	.4679	.4871	.3864	.3716	.6996	.7529	.7915	.8628	.8990	.9097
		.3607	.4646	.7629	.7915	.8990	.9259	.9765	1.0471	1.0759
			.7610	.8393	.9207	1.0115	1.1027	1.0716	1.0154	.9938
				.9259	1.0759	1.0716	.9696	.9178	.8820	.8835
					1.0397	.9310	.8835	.9619	1.0548	1.0772
						.8986	1.0548	1.0721	1.0685	1.0691
							1.0658	1.0666	1.0682	1.0158
								1.0158	.8612	.8748
									.9215	.9680
										.9833

COLLIMATOR COMBINED OPTICS, DUMMY COLLECTOR, 50 FT THROW
AXIAL DISPLACEMENT MIRROR 4, -1/4
AREA= 54 X48 WITH 1.5 SQUARES

.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0094
	.0000	.0000	.0207	.0684
		.0245	.0796	.1236
			.1264	.1527
				.2011

.0000	.0000	.0022	.0278	.0516	.0845	.1060	.1185	.1264	.1320	.1344
.0003	.0278	.0626	.1020	.1236	.1385	.1476	.1584	.1686	.1774	.1823
.0468	.0978	.1264	.1437	.1614	.1873	.2087	.2288	.2499	.2674	.2797
.1158	.1402	.1614	.1970	.2288	.2797	.3427	.3590	.3354	.3141	.3062
.1476	.1823	.2228	.2934	.3595	.3141	.3147	.3944	.4738	.5079	.5244
.1970	.2499	.3504	.3141	.3454	.4915	.5508	.5363	.5146	.4921	.4827
.2674	.3590	.3064	.4738	.5492	.5146	.4732	.4654	.5215	.5396	.5457
.3542	.3275	.5244	.5323	.4732	.5086	.5515	.5875	.6158	.6440	.6679
	.5382	.5146	.4782	.5457	.5994	.6679	.8150	.9874	1.0597	1.0761
		.4854	.5581	.6268	.8150	1.0597	1.0425	1.0477	1.1074	1.1396
			.6440	.9332	1.0631	1.0748	1.1806	1.2009	1.1569	1.1334
				1.0425	1.1396	1.2009	1.1008	.9874	.8995	.8806
					1.1793	1.0205	.8806	.9417	1.0745	1.1196
						.8850	1.0745	1.1700	1.1693	1.1482
							1.1735	1.1334	1.1568	1.1131
								1.1131	.9743	1.0539
									1.0525	.9908
										1.1655